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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS.

NOTES ON IRRIGATION

IN

CONNECTICUT AND NEW JERSEY.

BY

C. S. PHELPS, B. S., AND EDWARD B. VOORHEES, M. A.

WASHINGTON:
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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., December 15, 1896.

SIR: I have the honor to transmit herewith, and recommend for publication as Bulletin No. 36 of this Office, two articles on irrigation in the Eastern United States, entitled, respectively, Irrigation in Connecticut, by C. S. Phelps, professor of agriculture, Storrs Agricultural College, and vice-director Connecticut Storrs Agricultural Experiment Station, and Irrigation in New Jersey, by Edward B. Voorhees, M. A., director of the New Jersey Agricultural Experiment stations and professor of agriculture in Rutgers College. These articles embody in part investigations conducted by the Connecticut Storrs and New Jersey Experiment stations.

Although irrigation has been practiced for many years in the Eastern States on a limited scale, especially on grass lands, it is only within a comparatively few years that any widespread interest has been manifested in the subject in this region.

In recent years, however, widespread drought, especially at critical periods in the life of certain crops, has drawn the attention of Eastern farmers and horticulturists to this subject, and there has been much discussion of the practicability of irrigation under humid and subhumid conditions. Truck farmers and fruit growers in regions accessible to good markets are beginning to appreciate the importance of irrigation, and there seems to be a demand for information on the practice as applied to Eastern conditions.

A popular discussion of the principles and practice of irrigation in humid climates was given in Farmers' Bulletin No. 46 of this Department. The present publication is intended to supplement this bulletin and to show the need and possibilities of irrigation in two representative Eastern States, the methods pursued and results obtained by those farmers who have undertaken to practice irrigation in these States, and the problems needing investigation.

In connection with the report on irrigation in New Jersey acknowledgment is due to Mr. C. C. Vermeule, author of Water Supply, Geological Survey of New Jersey, 1894, for important data concerning the water supply of the State accessible for irrigation, and the estimated cost of irrigation plants, and to Mr. George A. Mitchell, of Vineland, for much statistical matter in reference to a number of the irrigation plants now in operation in the State.

Respectfully,

A. C. TRUE,
Director.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

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IRRIGATION IN CONNECTICUT.

By C. S. PHELPS, B. S.,

Professor of Agriculture, Storrs Agricultural College, and Vice-Director, Connecticut Storrs Agricultural Experiment Station.

INTRODUCTION.

Up to the present time little has been done in the Eastern States in the use of irrigation either on farm, garden, or orchard crops, but its great value has been demonstrated in a few striking instances by some of our leading fruit growers, and these instances, together with the general interest that is being manifested in the subject, show the need of inquiry. Within the past few years there has been a lively agitation of the subject through the agricultural press of the East, and farmers and small fruit growers are beginning to appreciate the value of artificial watering, and an increasing demand seems to exist for all the information obtainable on the subject.

In the eastern portions of this country the intensive system of agriculture is rapidly replacing the extensive. This has become necessary because of the rapidly increasing population and a corresponding increase in the value of lands. In the past fifty years the agriculture of New England has been entirely changed. A system of general husbandry has been largely replaced by special branches of farming. The many thriving manufacturing cities and towns that have been built have caused a great demand for fruits and vegetables. These products have proven especially profitable where markets are near at hand. The high value per acre and the active and increasing demand for fresh fruits and vegetables have induced many of our farmers to enter upon the production of these crops, and it is in such lines of farming as fruit growing and market gardening that irrigation has its highest value. Where the cost of cultivation is large the losses from drought are felt all the more severely, as the expenses are essentially the same whether a half crop or a full crop is harvested. In the eastern part of this country droughts are not usually of long duration, but short, severe droughts are common, and they cause heavy losses to market gardeners and fruit growers. Losses of from $100 to $200 per acre as a

result of a few weeks' drought are not uncommon. The area devoted to strawberry culture during the season of 1895 in Connecticut is estimated at not less than 500 acres. With this total acreage a loss of $100 per acre means, for one small State, a loss of $50,000 on a single crop.

The experience of practical men and the experiments cited beyond indicate that an investment in an irrigation plant where market garden crops and small fruits are grown will pay exceptionally good interest.

NEED OF IRRIGATION IN CONNECTICUT.

The majority of people fail to realize that irrigation has any place in New England agriculture. The annual rainfall in this region is generally thought sufficient to meet the needs of most, if not all, of the farm crops grown, and that any considerable expenditure of money for irrigation would not repay the expense except in very exceptional cases. The rainfall, however, is very unevenly distributed throughout the year. Short, severe droughts are a characteristic of the climate. A high temperature, accompanied by drying winds, will in a week's time frequently cause the crops to wilt, and in less than two weeks the crop prospects may be nearly ruined.

A rainfall of 3 inches per month, if fairly well distributed throughout the month, would probably produce an average growth of most farm crops. With less than this amount of rainfall many crops fail to make a normal development. During the past eight years the Connecticut Storrs Experiment Station has made observations on rainfall during the growing season at about a dozen different places in the State, and from these and others made for the New England Meteorological Society are taken the following figures for the rainfall for the five summer months:

Rainfall in Connecticut during summer months, 1888 to 1895.

Year.	May.	June.	July.	August.	September.	Total five months.	Average per month.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1888	....	1.58	2.00	5.59	8.43	....	4.40
1889	3.75	3.53	11.35	3.92	4.67	27.22	5.44
1890	5.19	2.96	4.29	4.29	5.45	22.18	4.44
1891	1.82	2.47	4.24	3.81	3.31	15.65	3.13
1892	5.31	2.65	3.80	4.35	2.17	18.28	3.66
1893	6.99	2.65	2.12	4.69	2.69	19.14	3.83
1894	5.07	.75	1.55	1.81	4.15	13.33	2.67
1895	2.26	2.74	4.36	4.54	2.44	16.34	3.27

From this table it will be seen that the average rainfall has been below 3 inches for June seven years out of eight, for July three years, for August one year, and for September three years.

The rainfall for the growing season (May to September), were it evenly distributed through the different months, would usually prove sufficient for the needs of most crops. From the above table it will be seen that the rainfall for different months is very irregular. While the

water which accumulates in the soil during the portions of the year when vegetation is not growing may be of some benefit to crops, yet a large part of the water used, especially where the ground water is quite a distance below the surface, must come from the rain that falls while the crops are growing. A remarkable instance of the excess of rainfall which often occurs when crops need the water least, and a deficiency during those months when crops use water most largely, may be seen in the rainfall data at Storrs, Conn., for the year 1895. The five summer months from May 1 to September 30 showed a total rainfall of 14.5 inches, while the two succeeding months—October and November—gave a rainfall of 13.7 inches.

There are very few seasons during some part of which a drought of more or less severity does not occur. With crops like strawberries, raspberries, early potatoes, and onions, a lack of rain for two or three weeks may lessen the crop by one-half or more. A striking illustration of the injury caused by short droughts was seen during the season of 1895 on one of the farms of this State where irrigation was being put in operation for the first time. A field of strawberries that had been set out in the spring of 1894 was on too high ground to be reached by conducting the water from the storage pond, while a field of the same size on another part of the farm was sprinkled from pipes laid on the surface. The irrigated area, with only three applications of water, gave a yield two and two-thirds times greater than that obtained where no water could be applied.

Many Connecticut soils are of such a character that they suffer readily from drought. Some of the best soils for market garden and fruit crops are light and sandy with gravelly subsoils. These suffer readily from drought, but when supplied with sufficient water give large crops of the best quality.

A strong argument in favor of irrigation in Connecticut is found in the high value per acre of many farm and garden crops. The following table shows the range of value per acre for some small fruits and market garden crops grown on unirrigated soil, as given by practical farmers. These were chosen because they have proven especially valuable in the few instances where irrigation has been practiced in this State:

Value of different crops per acre.

Strawberries	$200 to $450
Raspberries	200 to 400
Asparagus	100 to 200
Cauliflower	200 to 400
Celery	200 to 300
Onions	150 to 300
Muskmelons	300

It will readily be seen that a loss of one-half on some of these crops when five or six acres are grown would cover quite an outlay for water. The two men in Connecticut who have made the most extensive use of

irrigation state that the cost of their irrigation plants was returned the first season by the increased crops obtained.

With crops like strawberries and raspberries the benefits derived from irrigation represent only a few weeks' labor and a small expenditure of money. So great is the gain derived from having an abundance of water for these crops at the right time that good profits have been obtained by the use of a road engine and force pump. In many places this form of power could be hired for a few days and large profits obtained from its use.

Before farming products were shipped long distances by rail, the prices obtained for the crop in any locality depended largely upon the supply in that immediate vicinity. If the season was not a favorable one for any particular crop and the yields were light, the increased price obtained often counterbalanced the deficiency in the yield, so that the weather conditions did not so largely regulate the profits. To-day, however, if in one locality there is a shortage in any crop that will bear long carriage, the markets may be stocked from places long distances away, where the weather conditions were perhaps favorable for large yields. The profits obtained by local growers are thus largely dependent upon the season.

METHODS OF IRRIGATION IN USE IN CONNECTICUT.

The sources of water for irrigating purposes in Connecticut are mainly from small natural streams, from ponds, and from springs. No instances are known to the writer of the use of water from wells for irrigating purposes in this State. The water is usually stored either in open ponds or in large tanks. The means of making the water available are through some form of power, such as a ram or windmill, or, when the source is high enough above the fields to be watered, it is conducted to and over the fields through open ditches or pipes. There are many instances in Connecticut where the water can be made available only by some form of power, as the water is below the fields upon which it is to be applied. There are two farms in the State where powerful rams have been very successfully used. Where the water is supplied by means of a ram or other pumping appliance it becomes necessary to economize in the use of water and to prevent losses by evaporation in order to reduce the expense. For these reasons it has been found more economical to apply the water from pipes distributed over the fields. The water is sometimes allowed to flow between the rows from pipes laid along one end of the field. In other cases it is applied by spraying. The cheapest and simplest method of distributing the water is by conducting through open ditches, and there are several instances where this is being successfully done.

HISTORY OF IRRIGATION IN CONNECTICUT.

There are a number of abandoned irrigation plants in Connecticut that were in operation forty years ago. One of these is located at

Salisbury, another at Torrington, and a third at Newtown. The one at Salisbury was owned and operated by Albert Moore. In 1866 he wrote regarding his use of irrigation:

I have raised enormous crops of corn without manure, and have had similar results with rye, oats, and potatoes. From a poor piece of land, yielding less than a ton of hay, white daisies, and large Saint John's-wort to the acre, I now get 3 tons of first-quality hay without plowing or seeding. The daisies and Saint John's-wort have entirely disappeared, and Canada thistles and other injurious plants do not attain a foothold on irrigated land. This I attribute to the very thick growth of grass, as I have counted from 8 to 12 grass plants on a square inch of irrigated turf, and not over one on the same area of unirrigated; but a few feet apart. Meadow moles and mice, grubs, and grasshoppers, and all other insects and vermin, cease their depredations on irrigated land.

All kinds of farm stock prefer the hay, and eat it with avidity, and do well on it. I have even known sheep to fatten on it alone in winter, and become fit for the butcher in the spring.

The meadow requires no other manure, and when the hay is consumed on the farm it contributes largely toward furnishing manure for other parts of the farm. Cattle eat the stems of the hay much cleaner than of other hay, as by growing so thick it is so much finer and less distasteful than hay from heavily manured land. I have frequently seen grass standing over 5 feet high, by measurement, on one side of an irrigating ditch, while on the opposite side, where the water could not reach, the grass was scarcely a foot high.

The irrigated portion of a large pasture is constantly fed down much closer and shorter than the adjacent portions, beyond the reach of the water. The grass on irrigated land not only starts earlier in the spring, but holds out later in the autumn, thus shortening the foddering season at both ends. The water tends effectually to keep off both early and late frosts. Even if a field of corn is flooded a few inches deep in a frosty night, it will escape the effects of the frost, and the same is true of tobacco and other like crops.

A small rill of water which flows but a month or two in the spring, if spread over the adjacent surface of grass, will, if continued yearly, soon show its good effects the entire season, and the effects of irrigation are often of the most reliable and durable nature.

I have never noticed any different effect from hard, soft, cold, or warm brook or spring waters. My theory is that all water contains fertility in solution, and by irrigation it is placed or even put into the mouths of the rootlets of plants and absorbed at once; that it is not so much the water itself as what it contains which causes the result.

I can point to large apple trees now standing and bearing well on a meadow irrigated profusely for the last fifty years. In another meadow young apple trees are doing well where the irrigation is applied both winter and summer.

The grape, currant, raspberry, Lawton blackberry, asparagus, tomatoes, spinach, horseradish, and other fruits and garden vegetables, which bring a high price in market, thrive well under irrigation, but it must be land naturally adapted to irrigation and not naturally wet.

The only ill effect which I have noticed is that the grass, if not cut when mature, is a little more liable to lodge or fall down, in which case the water should be withheld at once, and the grass cut without delay, and the water let on for a second crop.

In 1866 Hon. T. S. Gold, secretary of the State board of agriculture, wrote in regard to the work on irrigation done by Mr. Thrall, of Torrington, and Mr. Mitchell, of Newtown:

Mr. Thrall has upon his place a stream large enough to turn a mill; and for the last twenty years he has irrigated, by water from this stream, a field of from 4 to 6

acres of low, sandy land, and which has been made to produce abundantly. I have never observed manure to have been used upon this land. The expense is not excessive. He first erected a cheap wooden dam to collect water for the supply of his fields. About ten years ago he removed this wooden dam and put up a stone dam at an expense of more than $100, for the purpose of raising water to a sufficient height to make it flow through his little channels and over his fields. His crop, of course, is large and fine; and he is one of our practical farmers who evidently thinks that irrigation pays well.

Mr. Mitchell has some 50 or 60 acres of hungry, gravelly soil, on the banks of the Housatonic River, which were as valueless as you can find anywhere, not bearing decent mullein stalks. He had graded most of it in a perfect manner. Most of the water comes from a large stream flowing through his farm, furnishing a never-failing and abundant supply. There are several factories on this stream adding to the value of the water. He uses, also, other smaller streams from the hills which drain from swamps, and this is found less useful. On the large stream Mr. Mitchell has a sawmill, and from the dam connected with it the water is taken. This dam went off two or three years ago, and before it was rebuilt his irrigated fields suffered much, some of the grass dying out entirely. His main ditch is 5 feet wide, about 4 feet deep, and nearly a mile in length. Branching from it is a flume or trough 100 feet or more in length and elevated some 10 feet, carrying a stream of water about 2 feet square across a hollow to an irrigated field. From the main trunks it is led in ditches of various sizes, growing smaller and smaller, until the whole of the water is used up. The whole work requires about 5 miles of ditch. These ditches are mostly elevated, made by embankments rather than excavations, so that by an ingenious contrivance of gates the water can be thrown out at any desired point.

A stream of water as thick as a man's hand, when turned on that dry and hungry soil, will be absorbed in running a few rods, until the ground gets filled up with fine particles from the water. There is no swamp grass there; it is clover and the better kinds of grasses. When I was there, he was mowing his second crop and cutting 1½ tons to the acre, perhaps 2 tons. It is not all as good as that. If there happens to be a little spot of a few feet that, owing to its elevation, is not irrigated at all, it is perfectly barren, and if there happens to be any place where his grade is too low, so that the water stands, it has killed out the grass, and weeds have sprung up, but in general the result is very wonderful and should encourage every one to use what water he can, especially in irrigating that class of lands.

Mr. Mitchell spoke of his orchard which was attacked by the borers. By the help of an embankment he ponded this to a depth of 1 or 2 feet. Though this was continued for several weeks, the trees have survived, and the borers have left. The grading has been done by scraping and carting earth, and by washing. An even surface with a gradual descent so that the water will just flow over the whole is necessary.

Whether all his operations are profitable or not, he accomplishes his purpose, and shows the wonderful effects of the application of water to land of that character.

IRRIGATION PLANTS IN USE IN CONNECTICUT.

There are several irrigation plants in active operation in this State at the present time, located in the towns of Meriden, North Haven, Glastonbury, Hamden, Thomaston, South Manchester, and Simsbury. These are the only ones known to the writer that are operated upon a commercial basis.

IRRIGATION ON THE FARM OF A. J. COE, MERIDEN.

Of the irrigation plants now in operation in this State one of the oldest is on the farm of Mr. A. J. Coe, of Meriden. Mr. Coe says that the work was started by his father about the year 1840, and that the

water was used for many years mainly upon the grass crop, although corn, potatoes, and other crops were irrigated when brought into the rotation, whenever the rainfall was deficient. For the first twenty years it was used mainly on grass and common farm crops. In 1863 Mr. Coe began to use the water on strawberries and raspberries, and has used it every year since whenever drought seemed to make its use necessary. In 1895 he used it on the two crops just mentioned, and upon tomatoes, asparagus, and cabbage.

The source of the water is a small stream that during seasons of average rainfall would just about flow through a 6-inch pipe without pressure. He finds that this stream supplies sufficient water for 15 acres, planted to a variety of crops. The water is stored in two large ponds. The upper one is used mainly for getting ice and to supply power for cutting feed and wood. The smaller pond, a little lower down the stream, is so located that the water can be conducted through a ditch for a distance of about forty rods and then distributed over the field in small ditches. The amount of water is sufficient to thoroughly irrigate a variety of crops if none of them require very large quantities of water during short periods of time.

Mr. Coe has not been able to estimate accurately the profits obtained from irrigation, as the crops grown are used very largely for home consumption. Those sold go to the local markets, which are often overstocked, and prices do not average as high as in some other cities. He, however, is thoroughly convinced that large profits can be obtained from irrigation where the expense of distributing the water upon the land is not too great.

IRRIGATION ON THE FARM OF E. C. WARNER, NORTH HAVEN.

Mr. Warner began his irrigation operations about ten years ago and has used the water mainly for strawberries and raspberries. The cultivated fields are so located that part of them may be watered by flowage from a pond supplied by springs and small streams. Others are on high ground and may be watered from tanks located on a hill near by. A ram is used for filling these tanks, the source of the water being numerous small springs, the water having been conveyed to a common point, making a pond of about one-half of an acre in area. A fall of 6 feet is obtained from the pond to the ram, and the water is lifted 60 feet in height, through 600 feet of pipe to the tanks referred to. As this system is essentially the same as the one described on the farm of Mr. Eddy (p. 19), no detailed description is necessary here. The water is used directly from pipes, being sprinkled upon the soil mainly by means of hose.

On the west side of Mr. Warner's farm a small stream flows through a pasture, and by building small earth dams and ditches the water was conveyed into a pond located a few feet higher than one of the strawberry fields. The fall along the rows of strawberries was very slight most of the distance, and the water was conducted across the rows near

one end and turned down the rows as needed. At one point in the field there was a knoll so high that the water could not be gotten upon a small area, but it was conducted around the knoll, and it then flowed readily along the rows again and over the rest of the field. Although no attempt was made to estimate the differences in yield, it was evident that the crop on this knoll was very much smaller and the fruit of much poorer quality than over the rest of the field. The plants also were so much injured by the effects of the drought that when seen in September, 1895, they presented a striking contrast to the plants only a few feet away where the water had been used. Mr. Warner thinks that the crop on the whole field was double what it would have been had no artificial watering been done. The entire expense of irrigation represented only a few days' work with men and teams, probably costing less than $25 when estimated at market rates of labor. So great were the benefits derived from this small effort that Mr. Warner at once set about making plans to enlarge his system, and during the fall of 1895 he built two large storage ponds a little higher up the stream, where he expects to have storage capacity and water sufficient for about 6 acres, all of which can be watered by direct flowage.

While Mr. Warner has gotten very beneficial results on raspberries with irrigation, he has also used it to advantage upon peach trees in times of severe drought during the fruiting season.

IRRIGATION ON THE FARM OF HALE BROS., SOUTH GLASTONBURY.

The Hale Brothers, of South Glastonbury, growers of fruit and nursery stock, have long felt the importance of irrigation in their business, and have for some time been maturing plans for using a supply of water near their farm for this purpose. During the fall of 1895 they began the laying out of one of the largest systems of irrigation to be found in the State.

A small brook has been dammed, and a reservoir thus formed. The source of the water is about 5,000 feet distant from the fields to be irrigated, and the fall is about 100 feet. Heavy cast-iron pipe 6 inches in diameter, joined together with lead, were used for 360 feet from the reservoir, and then a 4-inch pipe for 1,900 feet, or until a fall of 50 feet was obtained, after which the size of the pipe was reduced to 3 inches. The pipe was carried along the top of the ridges of the farm, and at points about 200 feet apart hydrants were placed so that the water can be taken from the main pipe and used for surface flowage or for sprinkling. It is believed that there is sufficient water to thoroughly irrigate from 45 to 50 acres of land mainly by surface irrigation. The contour of the land and the character of the soil are such that water can be distributed between the rows of plants and trees so as to give a very even distribution.

The Messrs. Hale propose to use the water on small fruits, and ultimately on peaches, being thoroughly convinced from experience that

the use of water on peach trees will prove profitable in seasons of severe drought during the fruiting time.

IRRIGATION ON THE FARM OF JOHN LEEK, HAMDEN.

On this farm there are about 5 acres under irrigation at the present time. The land is low, nearly level, lying between the slopes of hills, and a small stream of water passes through the irrigated area near the center. The surface soil is a fine, gravelly loam that has apparently been washed in from the surrounding hills. At a depth of about 3 feet is a gravelly clay hardpan, beneath which is a stiff clay.

The land is naturally quite fertile, but the compact subsoil prevents the escape of surplus water, while in case of drought the land bakes and cracks badly. The physical condition of the soil has been greatly improved by drainage. The texture of the soil is firm enough to prevent washing, and the fall is about 3 feet to 100, so that conditions are favorable for surface flowage from open ditches.

A small stream of water that would, in times of an average flow, readily pass through a 5-inch pipe enters the farm through a narrow ravine, and has a fall of about 15 feet for the first 20 rods back from the irrigated area. About 15 rods up this ravine has been built a dam and a small storage pond, from which the water is conveyed in open ditches upon different parts of the field.

The whole area has been laid out in three lots in such a way that water can be conveyed to the ends of the fields and allowed to run down between the rows of the crops, some of the land having been graded in order to make this practicable. The water has, in a small way, been used on a variety of garden crops, but quite extensively on strawberries and celery. Mr. Leek is so well pleased with the results on these crops that he is planning to enlarge his storage pond and to use the water more extensively in the future.

The conditions on this farm are similar to those found on many Connecticut farms, in that the water can be obtained for irrigation at a nominal cost.

IRRIGATION ON THE FARM OF W. A. LEIGH, THOMASTON.

This farm is located in the Naugatuck Valley, at the base of a steep bluff that rises, quite abruptly, about 350 feet above the valley. Over this bluff pours a small mountain stream that is quite constant and of volume about sufficient to fill a 6-inch pipe in times of an average flow. This stream is fed by springs near the top of the bluff. By building a dam across a narrow ravine a storage pond covering an area of about 5 acres was formed, 300 feet above the irrigated fields.

The water is conducted through a 3-inch pipe laid on the surface of the ground, and is used in furnishing power for a small granite works as well as for irrigating. The pressure is so great—about 125 pounds to the square inch—that a small stream runs a water wheel furnishing 7 horsepower. The water is used for irrigating mainly at night.

For irrigating purposes branch pipes of $1\frac{1}{2}$ and 1 inch in diameter are laid on the surface of the ground, the lines of pipe being placed about 50 feet apart. Short pieces of hose are attached to these lines of pipe, once in about 50 feet, and the water is applied by spraying through $\frac{3}{8}$-inch nozzles. The pressure is so great that three or four of these $\frac{3}{8}$-inch streams may be kept playing at one time from a single pipe. The water is forced to a great height and spreads out into a fine spray, covering a large area, like a lively shower.

Mr. Leigh has about 15 acres upon which irrigation might be applied. Its use, however, has been confined to strawberries. He began using the water on this crop in 1887 and has used it every year since. In 1895 about 3 acres were under irrigation.

The water is first used about the time the plants bloom and is continued if needed till near the end of the fruiting season. Mr. Leigh prefers to apply the water largely at night, as he finds it blackens or "blights" the leaves if used near the middle of the day when the sun shines brightly. No accurate comparisons as to the yields with and without irrigation have been made, but Mr. Leigh estimates that double the crop has been obtained as a result of the free use of water.

IRRIGATION ON THE FARM OF JOSEPH ALBISTON, SOUTH MANCHESTER.

Mr. Albiston probably has the oldest irrigation plant in Connecticut. The privilege was granted in 1796, the water being taken from a small stream at a point about 60 rods above the limits of the farm. The stream is of sufficient size to about fill a 10 or 12 inch pipe in times of an average flow. The brook passes through part of the farm, and about 7 acres of land either side of the stream can be watered. There are two small irrigation plants now in use on the farm. In the oldest the water is conveyed in an open ditch. The fall of the stream is such that at a very small expense for a dam practically all of the water of the stream can be turned into the ditch. About 5 acres can be watered by this means. This plant was very extensively used in irrigating grass for many years, but within the past twenty years it has been used to water small fruits and vegetables.

A second plan of irrigation was adopted, for a part of the farm, a few years ago. At a point near where the same brook just referred to enters the farm a dam and small pond were constructed. They are now used in irrigating about 2 acres of the bottom land along the brook.

Most of the soil of the irrigated area is a gravelly loam, much of which has been washed down from the surrounding hills. About 2 acres of the bottom lands are of a more compact soil, with a hardpan subsoil. This area has been underdrained and much improved. The surplus water used in irrigation is now readily conveyed away through the underdrains.

Of the area watered from the canal about 3 acres are nearly level, having a fall of less than 5 feet in 400. The water can be conveyed by

a branch ditch along one end of this area and then, as needed, turned down between the rows of small fruits and vegetables. About 1 acre on quite a steep slope just below the main ditch is thoroughly watered by seepage from the canal.

Mr. Albiston has found the use of irrigation especially profitable on strawberries. In 1894 32 square rods of land planted with Crescent strawberries produced at the rate of 10,400 quarts per acre. In 1895, with a very severe drought at the time of fruiting, Mr. Albiston claims that his crop was the best that he has ever produced. The blackcap raspberries and blackberries have each year produced exceptionally fine crops under irrigation. Potatoes have been irrigated during seasons of drought. In 1894, which was an exceptionally unfavorable season for potatoes, the crop obtained by irrigation yielded at the rate of 300 bushels to the acre.

IRRIGATION ON THE FARM OF J. C. EDDY, SIMSBURY.

Mr. Eddy is making a specialty of small fruits and vegetables, and the severe droughts which have occurred each summer for the past three or four years have impressed upon his mind the great importance of an abundance of water for the financial success of his business. The farm is located near the western limits of the Connecticut Valley, and is composed mainly of a light, porous, rather sandy soil that requires large quantities of water to grow crops successfully. A small stream within a narrow valley passes through the farm, and the cultivated lands lie mainly upon slopes just outside this valley. The water of the stream is not very cold, and the temperature is raised somewhat by allowing the water to stand in a storage pond where a large surface is exposed to the direct rays of the sun. The water appears to contain quite a little organic matter, and doubtless furnishes considerable plant food.

It has been found impossible to bring the water upon any save a small portion of the farm by damming the stream and building ditches, and it would have cost quite a sum to have gotten the right of way, as the water would need to be taken from a point beyond the limits of the farm; therefore, a ram was adopted as the most feasible means of making the water available for irrigation. In order to get the necessary fall for running the ram, a canal about 40 rods in length was dug along the outer edge of the valley. From the lower end of this canal the water makes a fall of 7 feet through a 6-inch drive pipe and forces a large ram located near the center of the valley. The water was turned into the canal by a small and inexpensive wooden dam. No more water is allowed to enter the canal than can be carried off through the drive pipe of the ram. The supply that flows in the brook is many times the amount that even the heaviest form of ram could lift.

At quite an elevation above the cultivated fields, on soil of a heavy, clayey nature, was located a small pond that usually became dry in summer. This was enlarged by dredging and by building an earth dam

on two sides. A storage pond was thus provided having an area of about half an acre and an average depth of about 4 feet, with a bottom tight enough to prevent much soakage. This pond is located about 80 rods from the stream at the nearest point, and high enough to give a good fall to most of the cultivated fields.

The water has to be lifted to a height of 70 feet before it enters the storage pond and is conducted through a 2½-inch iron pipe. Connections can be made with this pipe at various points between the ram and

FIG. 1.—Irrigation system on the farm of J. C. Eddy, Simsbury, Conn.

the storage pond, and thus the same pipe can be used to conduct the water to the pond or directly to the fields where needed for use. The main pipe used is 2½ inches in diameter, and is laid sufficiently deep not to interfere with cultivation. Mr. Eddy has been so successful in his operations during 1895 that he proposes to enlarge his plant and to force the water over a large area of land planted in peaches on the opposite side of the valley from the storage pond.

The accompanying plan of Mr. Eddy's farm will give a clear idea of

the position of the ram, the storage pond, the lines of pipe, and the various fields upon which the water may be used. The different fields upon which the water was used in 1895, as well as some of the fields where it is proposed to use it are marked out by dotted lines. It will be noticed that the land on either side of the brook to the east of the pond slopes rapidly toward the valley. The slope is here so great and the soil of such a porous nature that the water can only be applied by sprinkling from hose. The proposed line of pipe to the high ground east of the valley is indicated by dotted lines.

The fields to the north of the farm buildings are watered through pipes directly from the storage pond.

Two acres of strawberries on the west side, which were irrigated during the season of 1895, were on soil of such a slope that either surface flowage or sprinkling could be used. Water is wanted in large quantities on strawberries during short periods of time.

The crops grown and successfully irrigated by Mr. Eddy during 1895 were strawberries, muskmelons, onions, and cauliflower. These have proven especially important crops because of their high value per acre and the fact that the farm is located at quite a distance from markets, where bulky crops giving smaller profits per acre would be expensive to market. With this variety of crops the water would not be needed in very heavy quantities at any one time during the season, unless it might be for a few days during the fruiting season of the strawberries.

Results of irrigation on strawberries.—Mr. Eddy had 4 acres of strawberries in 1895. Two of these were located on high ground at the east side of the farm and could not be irrigated, and the other two on quite low ground north of the buildings. A severe frost in May appeared to have destroyed many of the blossoms and lessened the crop prospects very decidedly for the 2 acres located on low ground, while but little damage resulted to those on the high ground. Owing to this condition larger returns were to be expected from the field located on high ground, provided rainfall had been abundant. As it was, however, a drought began early in June and seriously reduced the strawberry crop all over the State. At the end of the season it was found that the 2 acres which were not irrigated gave a yield of 150 crates (32 quarts each), while the 2 acres that were irrigated yielded 415 crates. After the first few days' picking, the fruit on the unirrigated field was much smaller and darker colored and averaged only about 8 cents a quart for the season, while that from the irrigated field averaged 11 cents a quart. It must be remembered, however, that the fruit from the unirrigated field had to be sold when the markets were heavily stocked with berries, while much of that from the irrigated area reached the market after prices had risen, owing to the general shortage from the effects of the drought.

The water was not applied until just before the picking season opened, although better results would probably have been obtained had the water been used two weeks earlier. The method of applying first adopted was surface flowage, but owing to the mulch between the

rows it was found that this method was a very slow one. For this reason the plan of sprinkling from hose was adopted. Condemned 2-inch fire hose, with a large sprinkler attached, was used. This would throw a powerful spray, covering an area about 20 feet in diameter. The pressure was sufficient to give a flow of 30 gallons per minute. With this flow it was found that one man could water an acre thoroughly in about ten hours.

Later experience (1896) shows better results by the temporary removal of the mulch and the application of the water by flowage.

Results on muskmelons.—When grown on light soil and forced along rapidly early in the season, muskmelons have generally proved a very valuable crop in this State. Much loss, however, has been occasioned by frosts before much of the fruit is in condition to market. It is claimed that by irrigation it is possible to get the melons into market considerably earlier than usual, and to get large crops before killing frosts occur. As the plants only cover a small portion of the ground early in the season, sprinkling seems to be the best method of applying the water, and where the soil is loose and porous, with considerable fall, sprinkling is without doubt the best method for the entire season. By applying water once in five or six days, when a lack of rainfall seemed to make it necessary, it is thought that a steady growth of the vines and an earlier and much larger crop was secured than could have been obtained without artificial watering. It appears also that irrigation may have had influence in improving the flavor of the fruit. This may be a valuable feature of irrigation upon this crop; however, further investigation will be necessary to establish it. The melon crop grown upon 1 acre by irrigation sold for $350, and the vines were "full of fruit" when they were killed by frost September 14.

Results on onions.—This crop did not suffer materially from drought during 1895 in this State. Mr. Eddy's crop, however, was grown upon very light soil, and the ground was thoroughly sprinkled once during the growing season. A small portion of the field could not be reached with the hose, and this was allowed to go without artificial watering. No measurements of the crop were made, but when visited by the writer while the crop was being harvested considerable difference could be seen between the crop on the irrigated land and that on the small strip that was not irrigated. One thing especially noticeable in addition to the smaller yield was the increased proportion of small onions where no water had been used.

Results on cauliflower.—About 1 acre of this crop was grown during 1895. The crop was grown on a field of medium-heavy loam only a few feet above the bottom lands of the valley. The fall across the field, lengthwise of the rows, was at the rate of 3 feet per hundred, and the water was applied to this crop by allowing it to flow between the rows. From a 2½-inch pipe, with a 2 inch hose, about 40 gallons of water per minute could be obtained, and only about eleven minutes were required

for the water to flow from one end of the rows to the other, a distance of 175 feet. The water was applied once in about five or six days if the lack of rainfall seemed to make it necessary. The cauliflower headed earlier than usual, and the crop sold readily at about $400 per acre.

EXPERIMENTS ON THE EFFECTS OF IRRIGATION ON STRAWBERRIES.

In June, 1895, the Connecticut Storrs Station began some experiments on the farm of Mr. Eddy, for the purpose of studying the effects of irrigation on the quantity and quality of strawberries, and to ascertain some facts regarding the profits to be obtained from the use of irrigation.

It is hoped that this will be the beginning of a series of experiments by this station on the effects of irrigation on a variety of crops. There are many questions that it seems desirable to investigate in connection with the subject, such as the different methods of applying water and the relative advantage of each, observations on soil temperature, determination of the amount of plant food supplied in the water used, and chemical analyses of fruits grown, for the purpose of determining the amounts of sugar in irrigated and unirrigated crops.

The work was undertaken so late in the season that observations were made only on the yield, and on the quality of the crop, as indicated by taste, appearance, and market value.

PLAN OF THE EXPERIMENT.

A section was chosen from a field of strawberries of about 2 acres in area. The soil appeared to be nearly uniform, and the conditions were favorable for applying the water. The field had been set to strawberries in the spring of 1894. The Haverland was the variety used, with every fourth plant in the row a Jessie, the latter being used for fertilizing the Haverlands. The plats were 115 feet long and 12 feet wide, three rows to a plat, two plats being irrigated and two not irrigated. Two rows were left between plats which were not included in the experiment, in order to thoroughly separate the irrigated from the unirrigated sections. The plats were to be irrigated as often as seemed to be necessary to get good commercial results.

RESULTS.

The following table gives the yields in quarts and pounds for each day when fruit was picked.

Yields of strawberries on irrigated and unirrigated plats.

Date.	Plat 1, irrigated.[1]		Plat 2, unirrigated.		Plat 3, irrigated.[1]		Plat 4, unirrigated.	
1895.	*Quarts.*	*Pounds.*	*Quarts.*	*Pounds.*	*Quarts.*	*Pounds.*	*Quarts.*	*Pounds.*
June 13	1.1	[2]1.6	4.0	[2]5.6	3.9	[2]5.5	3.0	[2]4.2
14	4.0	[2]6.0	6.0	[2]8.4	4.0	[2]5.6	6.0	[2]8.4
15	12.0	[2]18.0	12.0	[2]16.8	13.0	[2]18.2	6.5	[2]9.1
17	19.5	29.1	18.0	25.6	25.0	34.8	18.0	24.9
18	14.0	19.1	6.0	8.0	14.0	17.9	3.5	4.9
19	14.0	19.1	5.0	6.5	17.0	23.2	4.5	6.5
20	21.0	27.8	3.0	4.0	12.0	15.7	3.0	4.3
21	16.5	22.2	3.0	3.2	11.8	14.8	3.0	3.6
22	10.0	12.4	3.0	4.4	6.0	7.4	5.0	5.1
24	25.0	34.0	4.5	5.3	([3])	([3])	([3])	([3])
25	[4]6.0	[4]8.4	[4]1.5	1.8	32.0	42.7	5.0	6.8
26	14.0	20.8	1.3	1.7	7.0	10.1	2.0	3.0
27	9.0	12.2	1.0	1.0	3.5	4.7	1.0	1.0
29	4.0	5.5	1.0	1.1	3.5	4.9	1.0	1.4
July 2	5.5	7.9	.5	.8	6.0	8.3	.5	.9
5	2.0	2.4	....	....	1.0	1.4	....	....
Total	177.6	246.5	69.8	94.2	159.7	215.2	62.0	84.1

[1] Watered June 10, 15, 18, and 20 and 21.
[2] Assumed to weigh same rate per quart as on June 17.
[3] Not picked.
[4] Not all picked.

Most of the picking was done by a representative of the station, as often as seemed necessary to have the fruit in good market condition. In case of the first three pickings no facilities were on hand for weighing, and the fruit was estimated to weigh the same per quart as that of the next succeeding picking. The weights per plat were figured from these data. All of the other pickings were both measured and weighed.

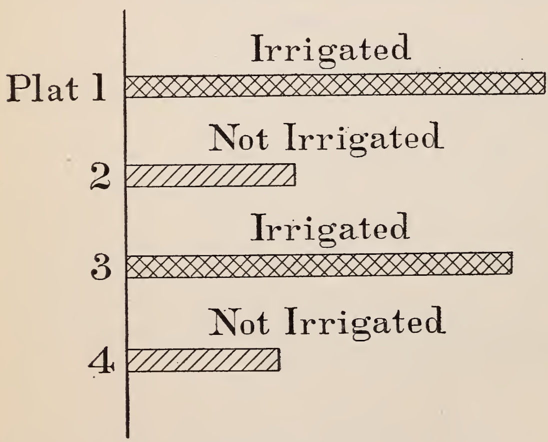

FIG. 2.—Comparative yields of strawberries on irrigated and unirrigated plats, 1895.

The effects of irrigating on the yield of strawberries is shown graphically in the accompanying diagram.

Water was used on the irrigated plats on June 10, 15, 18, and 20. The water was applied by means of 2-inch hose from a 2½-inch iron pipe laid on the surface of the ground. The size of the stream and the force of the water was sufficient to give 30 gallons (about 1 barrel) per minute. At this rate of flow one man could water, by sprinkling, about 1 acre per day. The ground was given a thorough wetting each time.

There was very little rainfall during the first twenty-five days of June. Seven-tenths of an inch fell between the 2d and 6th, but from the 6th to the 22d no rain whatever fell; on the 22d there was 0.25 inch, and after the 25th of the month rain was quite abundant. Strawberries generally began to feel the effects of the drought by June 17, before the picking season was more than one-third through.

It will be noticed that for the first two pickings the results were in favor of the unirrigated plats, and that the yields on the unirrigated plats were nearly as great as on the irrigated until after June 17. For the second picking (June 14) the two watered plats only gave 8 quarts, while the two not watered yielded 12 quarts. This tends to show that irrigation retards the development of the fruit and causes it to ripen a little later. The same condition was noticed on the larger fields of this farm. During the first few pickings the fruits from the unwatered plats were found to be sweeter, but those from the watered plats were larger and "looked 3 cents per quart better."

On June 17 the leaves of the plants on the unirrigated plats began to wilt and the berries to shrivel. The plants on the unwatered plats continued to dry, the leaves began to fall, and the fruit was small, dark colored, shriveled, and seedy.

On June 24 the writer visited the fields and found the plants on the unirrigated plats drying badly; leaves shriveled and many dry and dead; fruit much smaller, darker colored when ripe, and shriveled and seedy; hulls shriveled, and fruit appearing overripe when picked.

On the other hand, plants on the irrigated plats looked fresh and vigorous, the berries were large, bright colored, and abundant, and much green fruit was developing. The fruit, however, was not quite as sweet as on the unirrigated plats.

The total yield on the two irrigated plats was 337 quarts and on two unirrigated 132 quarts. This was at the rate of 5,318 quarts for the irrigated and 2,083 quarts for the unirrigated. The fruit from the unirrigated plats had to be sold for an average of 9 cents per quart, while that from the irrigated areas brought 11 cents. At these rates per quart the fruit on the irrigated plats sold at the rate of $584.76 per acre and that on the unirrigated at the rate of $187.47 per acre, a difference of $397.29 per acre in favor of irrigation.

It will be readily seen that with only 2 acres of strawberries the increased returns obtained, during one season by the use of water, would afford quite a sum toward covering the expense of an irrigation plant.

SUGGESTIONS REGARDING IRRIGATION.

The surface contour of most of the land of Connecticut, and in fact of all New England, is such as to facilitate the utilization of water for irrigation. The land is undulating and of such a slope as to readily admit of the conveyance and application of water. Streams, ponds, and springs are common, and except in cases of severe droughts these

furnish an adequate supply of water for irrigating. Many crops like strawberries, raspberries, and early vegetables need irrigating, if at all, early in the season. The supply of water is then often sufficient, when perhaps later in the season it would not be ample. Much of the land that would be improved by irrigation is found in valleys, in the proximity of streams and ponds, which in many cases are high enough for the water to be applied by gravity on the areas below, and the cost of getting the water is merely nominal. The soils used for our most profitable crops are generally light, porous, and leachy, and are just the class of soils that need irrigating; while our best money crops, such as small fruits and vegetables, commonly grown on these soils, are heavy users of water. There is no need of drainage in connection with irrigation on soils of this class, as is often the case where the subsoil is compact.

SOURCES OF WATER AND MEANS OF MAKING IT AVAILABLE.

The sources of water for irrigation in Connecticut are natural ponds, streams, springs, and wells. In many cases ponds are so located that water can be conveyed from them to fields on lower ground by means of open ditches. The expense for conveying the water will depend upon the distance and the character of the ground to be passed through. This is often the cheapest method for securing water. When the supply is great the loss of water occasioned by seepage from the ditch, or by evaporation is not of serious consequence. There are a few ponds in the State where by piping over higher ground and then on to land below the surface of the pond the water can be siphoned over and thus made available.

The fall of many of the small streams is so great that by building a dam the water might be turned from its natural course and conveyed in ditches along the outer edge of the valley and then allowed to flow over the surface of the fields back of the natural stream. In many cases the water running away from mills might be applied by flowage. The water from several springs may sometimes be conveyed to a single point and then held in a small pond from which it may be drawn as needed. Where only small areas are to be irrigated, wells may be made a source of water supply. The well must afford a large flow and should be so located that the water can be stored at some point at least 25 feet above the fields to be watered. In many cases bored wells might be utilized and afford a heavy flow of water.

IRRIGATION IN NEW JERSEY.

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INTRODUCTION.

The question of irrigation in what are regarded as the humid, or regions of sufficient annual rainfall of this country, is beginning to receive considerable attention, and the interest now aroused may be traced rather to changes which have taken place in the character of the farming than in any marked changes in the character of the seasons and in the annual rainfall.

In New Jersey, as well as in other Eastern States contiguous to the large cities, there has been a rapid increase in the area devoted to market-garden products, fruits and berries, or crops of relatively high value, and a corresponding decrease in the area devoted to old-line farming, or to crops of comparatively low value. This change in the nature of the crops grown is, as a rule, accompanied by a change in practice, that is, what is known as the "intensive" system of farming is more largely adopted; large quantities of manures are applied and crops rapidly succeed each other, all supplied with an abundance of food. Furthermore, earliness and high quality of products are of relatively greater financial importance than formerly, and these conditions can not be secured without a continuous and abundant supply of water. The wider dissemination of accurate information concerning the principles which govern in the management of soils and in the feeding of crops and the means now afforded for combating insects and diseases enable the producer at the present time to largely control the conditions other than weather. The late frost in spring and early frost in autumn, floods, and the spring and midsummer droughts are still beyond his control, and the frequency of the latter are the cause of very great losses annually.

The lack of water, particularly for quick-growing vegetables, small fruits, and berries, not only seriously affects both their yield and quality, but many times causes complete failure. The necessity of utilizing all the means at hand for overcoming these difficulties is, therefore, apparent and justifies a careful inquiry concerning the possibilities of

irrigation in those regions in which crops are more or less injured from year to year either through a lack of sufficient rainfall or through its unequal distribution.

In carrying out the investigations here recorded, particular inquiry was made along the following lines: (1) Need of irrigation in New Jersey; (2) areas capable of being watered by gravity and accessible water supply for this purpose; (3) estimated cost of irrigation; (4) use of irrigation in the State, methods used, and the results secured; and (5) irrigation experiments in New Jersey.

The meteorological records of the State afford abundant proof that there is very frequently a shortage of water during the growing season, due both to a deficiency in rainfall and to its unequal distribution, and that the most serious shortage occurs in those sections peculiarly adapted for the growth of vegetables and small fruits.

The data in reference to rainfall, in connection with careful measurements of the flow of streams, show that the State possesses a large supply of water for purposes of irrigation, which careful surveys indicate may be made accessible at a reasonable expense.

That this valuable resource of the State may be utilized with profit is illustrated by the examples given, derived from actual experience. The financial returns secured in these cases were profitable, even though those engaged in the work were inexperienced in all matters pertaining to irrigation. With proper knowledge of methods, the advantages derived doubtless would have been very much greater.

The experimental plant now in operation on the farm connected with the New Jersey stations has for its object the study of the necessity of irrigation for a wide variety of crops, the amount of water required, and the various methods of application.

NEED OF IRRIGATION IN NEW JERSEY.

The need of irrigation in some portions of the State has been seriously felt several times during the past fifteen years, and especially during the year 1895, which is still fresh in memory. This need is not so apparent when we merely consider the average rainfall throughout the State, which varies from 44.09 inches in the northwest to 49.70 inches on the seacoast, the main law of change observable being a quite steady decrease as we go inland from the coast. It is, nevertheless, a fact, that our entire rainfall occasionally sinks to 31.5 inches in some localities, or as low as the annual rainfall on the borders of the subhumid region of the West, and also that droughts occur during the growing months from April to August, inclusive, even more frequently than is popularly supposed. If even one of these months shows a serious deficiency of rainfall below the average, some crop is likely to suffer. In order to show how often this has occurred in the past a table has been compiled from the longer series of rainfall records obtainable,

which shows what percentage of the years covered by the records in each case show a deficiency of 1 inch or more below the average rainfall:

Percentage of years in which rainfall during growing season has been 1 inch or more below the average.

	Years of record.	April.	May.	June.	July.	August.	Deficiency for— One month.	Two months.	Three months.
New York	1836–1895	33	35	35	33	39	75	42	21
Newark	1844–1895	32	28	36	40	32	....	....	....
New Brunswick	1854–1895	35	28	32	47	40	....	....	....
Philadelphia	1825–1895	34	32	32	37	38	88	56	30
Moorestown	1879–1895	7	27	27	33	27	....	....	....
Vineland	1868–1895	2	34	29	50	40	....	....	....

Taking each month by itself, we find that the longer records show generally that the deficiency occurs about one-third of the time. The fact that it is less for Moorestown and Vineland for certain months is probably due only to the shortness of the records. The second part of the table shows a fact which is more serious, namely, that during the seventy years covered by the Philadelphia record, 88 per cent of the years show at least one month of this critical period deficient, while 56 per cent show two or more months deficient, and 30 per cent three or more months. The only reason that New York shows a less proportion is that the record does not include the years from 1825 to 1835, which were dry ones. After a careful analysis of all the rainfall records of the State we are convinced that during this period of seventy years any part of the State would have been subject to as great and as frequent droughts as are shown by the Philadelphia records.

Observation confirms what we should naturally expect, that our average rainfall is that which is most conducive to luxuriant vegetation, that is, to good crops. We should expect this because this average represents conditions which have generally caused our State to be productive. If we turn to the records of rainfall we find that those years which approximate the average in amount and distribution of the rainfall have almost invariably been very productive ones.

We find from our rainfall records that the period from 1860 to 1866 shows a remarkably uniform rainfall during the growing months, generally close to the average. In the following table the rainfall for certain notably dry years of recent occurrence, with the average rainfall for certain stations which fairly represent the State, is shown.

Rainfall of average and of some deficient years.

NEWARK.

	April to August.	Spring.	Summer.	Year.
	Inches.	*Inches.*	*Inches.*	*Inches.*
1880	17.38	8.96	13.32	37.34
1881	11.28	11.45	6.66	39.00
1882	14.61	10.89	6.91	51.70
1885	14.94	6.49	10.48	43.59
1894	10.42	7.69	4.62	40.60
1895	19.14	10.00	11.88	39.53
Average	20.38	11.46	12.83	46.70

Rainfall of average and of some deficient years—Continued.

NEW BRUNSWICK.

	April to August.	Spring.	Summer.	Year.
	Inches.	*Inches.*	*Inches.*	*Inches.*
1880	17.79	7.90	14.76	37.17
1881	11.32	8.42	8.47	38.46
1882	15.86	10.76	7.72	48.66
1885	15.41	5.23	11.26	36.70
1894	16.43	11.02	7.00	48.06
1895	10.68	10.68	11.62	39.25
Average	21.34	11.37	13.74	46.89

PHILADELPHIA.

	April to August.	Spring.	Summer.	Year.
1880	17.47	6.50	14.50	33.58
1881	9.33	7.15	6.01	30.21
1882	16.85	10.75	9.67	45.58
1885	16.19	6.99	9.89	33.35
1894[1]	23.12	18.56	6.70	55.68
1895[1]	16.38	11.73	8.62	35.90
Average	19.89	10.74	12.48	43.35

VINELAND.

	April to August.	Spring.	Summer.	Year.
1880	22.63	10.95	18.03	51.71
1881	13.01	10.10	8.18	42.48
1882	20.26	11.69	12.88	54.01
1885	13.16	6.36	7.71	35.43
1894	24.62	18.72	7.71	55.19
1895	17.49	13.48	8.09	38.36
Average	19.69	11.22	12.98	47.87

[1] Moorestown.

For the first four of these years the relative severity of the droughts is well exhibited by the deficiency of the rainfall for the five growing months from April to August. In 1881, the driest year of all, this deficiency ranged from 9 to 10.5 inches, although Vineland shows but about 7 inches. The year 1885 shows generally about 6.5 inches deficiency. The years 1881 and 1894 were so dry as to cause the forests in the northern part of the State to turn brown, and numbers of trees were actually killed, showing that the limit of endurance of the forests had about been reached. We find that at Newark the deficiency from April to August was 9.1 inches in 1881, and 9.96 inches in 1894. The average deficiency for the northeastern part of the State was probably about the same for both years. The severity of the drought of 1894 is not well shown in the rainfall from April to August at New Brunswick, Philadelphia, and Vineland, but taking the summer rainfall alone it becomes more apparent. So in 1895, the tables fail to show the full severity of the drought, but the following table exhibits it more satisfactorily for both these years:

Rainfall during droughts of 1894 and 1895.

	May to August—			June to August—		
	1895.	Average.	Deficit.	1894.	Average.	Deficit.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Kittatinny and highlands	13.92	16.23	2.31	5.21	12.35	7.14
Red sandstone plain	14.87	16.90	2.13	6.43	12.86	6.43
Southern interior	11.45	17.82	6.37	6.95	13.22	6.27

This table is made up from the average of a large number of stations for each district, taken from the records of the State Weather Service, to which we are indebted for much of our data. The drought of 1894 was confined to the summer months, and was slightly more severe in northern than in southern New Jersey when measured by the deficiency of rainfall alone. The drought of 1895 was much less severe in northein than in southern New Jersey owing to the fact that it set in one month later, September showing about 1 inch of rainfall, while the deficiency up to the end of August had only been about 2 inches, whereas in southern New Jersey August showed only about 1 inch of rainfall and September the same amount. It is interesting to compare the amount of rainfall shown in these tables with that of western Kansas, where the mean annual temperature is about the same as that of southern New Jersey, and where irrigation has been found to be necessary for profitable agriculture. In those places at which the average rainfall is about 20 inches per annum, that of spring is 4.7 inches, and that of summer 7.9 inches, making a total of 12.6 inches for the two seasons. It will be seen that the above dry periods approach these figures. Another interesting comparison is that of the next table, which is compiled from the report of the Kansas State Board of Agriculture.[1] This shows the rainfall and crop conditions where the average yearly rainfall happens to be almost exactly that of our driest years. It will be seen that from April to August the average rainfall of this region is 20.50 inches, while that of the Kittatinny Valley and highlands is 19.75 inches, the red sandstone plain 20.53 inches, and the southern interior 21.67 inches for the same months. The temperature is also much the same as that of our southern interior.

Rainfall and crop conditions, Riley County, Kans.

Year.	Rainfall.				Yield per acre.			
	April to August.	Spring.	Summer.	Year.	Wheat.	Corn.	Oats.	Potatoes.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
1872	24.84	9.79	15.97	35.78	14	38	25	68
1873	22.47	10.92	12.26	29.08	15	45	33	132
1874	8.12	3.75	4.74	17.73	11	2	16	5
1875	10.75	5.17	6.69	17.96	14	41	28	90
1876	34.20	17.21	20.95	45.78	13	40	30	100
1877	25.68	14.68	13.70	43.79	15	45	50	52
1878	26.45	7.83	20.39	39.10	16	42	48	67
1879	20.00	5.00	15.00	36.13	11	45	35	50
1880	21.03	5.32	16.21	29.11	11	32	24	73
1881	13.36	8.98	5.13	28.94	9	17	37	14
1882	20.71	9.70	11.68	28.35	22	50	45	80
1883	24.86	8.24	17.67	36.79	19	40	50	80
1884	23.43	10.22	15.57	33.62	23	47	41	110
1885	15.88	8.33	7.55	24.90	12	30	40	100
1886	19.96	11.18	10.33	28.85	16	25	35	75
1887	17.46	5.81	12.07	29.88	8	12	30	80
1888	17.73	6.11	14.10	31.29	19	29	36	20
1889	22.07	9.78	14.18	30.87	22	50	41	....
Average	20.50	8.78	13.01	31.55	15	35	36	65

[1] For the quarter ending December 31, 1889, p. 142.

Average yield and value of crops in good and bad seasons, Riley County, Kans.

Crop.	Average yield per acre.		Value per bushel, New York, 1890–1894.	Excess of good over average.		Excess of good over bad.	
	Good crops, 1882–1884.	Bad crops, 1874, 1881, 1887.		Amount.	Value.	Amount.	Value.
	Bushels.	*Bushels.*	*Cents.*	*Bushels.*		*Bushels.*	
Wheat	21	9	84	6	$5.04	12	$10.08
Corn	46	10	55	11	6.05	36	19.80
Oats	45	28	28	9	2.52	17	4.76
Potatoes	90	33	40	25	10.00	37	14.80

The years 1882 to 1884, inclusive, were very fruitful ones, and they show that with spring and summer rainfall amounting to from 22 to 25 inches in all, that country will yield 21 bushels of wheat per acre, 46 bushels of corn, 45 bushels of oats, and 90 bushels of potatoes, whereas the average crop for the eighteen years has been wheat 15, corn 35, oats 36, and potatoes 65 bushels. This is a striking illustration of the influence of rainfall in determining the yield of crops. It will be noticed that the total of the rainfall from April to August for these best years is about the same as the average for New Jersey, while the poorest years exhibit conditions quite similar to our own driest years. Thus we have in 1874, 8.12; in 1875, 10.75; in 1881, 13.36; and in 1887, 17.46 inches of rainfall, and in all these years most of the crops are very poor. If we compare the dry years in the table (p. 29) showing rainfall at different points in New Jersey we notice that the rainfall from April to August ranges from about 9.33 up to 17.79 inches, excepting in a few cases already pointed out, where the total from April to August does not fairly represent the severity of the drought. Taking the rainfall by seasons, the table (p. 31) shows a range for the driest season of the poor years of from 3.75 to 5.81 inches, while the table of New Jersey rainfall shows a range of from 4.62 to 8.62 inches. In general it will be seen, therefore, that while the average yearly rainfall of western Kansas is only about three-quarters of that of New Jersey, the rainfall during the growing months is quite similar to that of New Jersey both in its range and its average.

It appears that if during this period the crop could have been maintained as high as it was in 1882, 1883, 1884, and 1889, when rainfall was sufficient, the annual gain in crop per acre would have been 6 bushels of wheat, 11 bushels of corn, 9 bushels of oats, and 25 bushels of potatoes, which, at the value per bushel given, would have amounted to an average of $5.60 per acre on these four crops, or 34 per cent of the value of an average crop. It will further be found that the average loss on bad crops, due to light rainfall, amounts to $12.36, or 71 per cent of the value of an average crop. This is only offered as an illustration, for the probabilities are that irrigation would have produced still better crops than we have taken as the standard, because even when the rainfall as a whole is sufficient there will often be months or parts of

months in which the drought will be so severe as to injure the crop to a certain extent; besides, it is highly probable that irrigation in New Jersey will be applied to the raising of much more valuable crops than those above taken for illustration, and the gain for these crops will be at the same rate per cent as for the less valuable crops of our illustration. We may therefore, without attempting exact estimates of what the profit of irrigation will be where so much depends upon the character of the crop and the efficiency of treatment, safely consider that an outlay of $10 per acre per annum will afford a wide margin for profit in the hands of a good farmer. It is a well-known fact that the returns from irrigation have in very many cases been such as would give an ample profit on a cost of $10 per acre annually. The preceding tables make it appear, then, that there is a good promise of profit in such irrigation as will supply at all times in New Jersey moisture equal to that of an average year.

The following table shows the average rainfall and temperature over the four important divisions of the State:

Average rainfall and temperature of different sections of New Jersey.

Month or season.	Kittatinny Valley and highlands.		Red sandstone plain.		Clay and marl region.		Southern interior.	
	Rain.	Temperature.	Rain.	Temperature.	Rain.	Temperature.	Rain.	Temperature.
	Inches.	° *F.*	*Inches.*	° *F.*	*Inches.*	° *F.*	*Inches.*	° *F.*
January	3.48	25.3	3.63	28.5	3.73	29.5	3.83	30.5
February	3.31	27.7	3.45	31.0	3.55	32.2	3.64	33.5
March	3.57	33.8	3.72	36.8	3.82	38.0	3.93	39.3
April	3.48	47.2	3.63	49.4	3.73	50.[illegible]	3.83	50.7
May	3.88	58.8	4.04	60.3	4.16	60.9	4.27	61.5
June	3.88	67.6	4.04	69.6	4.16	70.1	4.27	70.6
July	4.05	71.3	4.23	74.3	4.35	74.6	4.46	75.0
August	4.42	68.6	4.59	71.3	4.71	71.9	4.84	72.6
September	3.57	61.7	3.72	64.5	3.82	65.1	3.93	65.7
October	3.33	50.1	3.45	53.6	3.55	53.8	3.64	54.1
November	3.57	40.4	3.72	43.4	3.82	44.0	3.93	44.7
December	3.57	29.8	3.72	32.5	3.82	33.3	3.93	34.1
Year	44.09	48.5	45.94	51.3	47.22	52.0	48.52	52.7
Spring	10.93	46.6	11.39	48.8	11.71	49.6	12.03	50.5
Summer	12.35	69.2	12.86	71.7	13.22	72.2	13.57	72.7
Autumn	10.47	50.7	10.89	53.8	11.19	54.3	11.50	54.8
Winter	10.36	27.6	10.80	30.7	11.10	31.7	11.40	32.7

This table makes clear the important bearing of temperature upon the relative dryness of these different sections. It is well known that droughts are felt in an increasing degree as we proceed from the Kittatinny Valley and highland region southward, but the table shows that the average rainfall increases in like manner, so that our driest section is the one having the largest average rainfall, and it has been fully established in the investigations of the run-off of streams[1] that evaporation increases about 5 per cent for each increase of 1 degree in mean temperature of the atmosphere. It will be seen from the table that between the Kittatinny Valley and highland regions and the southern

[1] Report on Water Supply, Geological Survey of New Jersey, 1894.

interior there is a difference of 4.2 degrees in the temperature for the year, which corresponds therefore to an increase of 21 per cent in the evaporation. This higher temperature fully accounts for the greater frequency of drought in southern New Jersey, and it is also seen in the table on page 29 and context that the greater average rainfall of that section is not accompanied by a greater rainfall during the driest seasons, which may be as dry here as elsewhere; consequently during such seasons the large increase of evaporation makes the drought more severe in this part of the State than farther north.[1]

The rain which falls upon the earth is partly dissipated by direct evaporation into the atmosphere; another part is taken up by vegetation, and practically all of the balance flows off in the streams. It is apparent, therefore, that if we have reliable measurements of the rain falling upon a given area, and of the amount flowing off in the streams during the same period, the difference between the two will represent the amount either evaporated or taken up by plants, most of which is ultimately also dissipated into the atmosphere, and may be included in the general term "evaporation." Our investigations show that evaporation is not directly proportional to the amount of rainfall, although it increases somewhat with increased rainfall. Formulas have been worked out[2] by which evaporation can be computed from the rainfall for each month of the year, the mean temperature of the locality being given. This enables us to determine just what amount of rainfall will be equivalent to the combined demands of evaporation and vegetation which we have included in the general term evaporation. The following table[3] gives the amounts for the different sections of the State :

Rainfall needed to be just equal to evaporation.

Season.	Kittatinny Valley and highlands.	Passaic watershed.	Red sandstone plain.	Southern New Jersey.
	Inches.	*Inches.*	*Inches.*	*Inches.*
Winter	0.97	1.10	1.16	1.27
Spring	3.19	3.70	3.91	4.31
Summer	9.46	11.12	11.97	13.37
Autumn	3.21	3.96	3.90	4.31
Year	16.83	19.61	20.94	23.26

Now, if rainfall should be just equal to the amounts given in the table, and we start with the ground full of water on April 1, the next table[4] shows how much water will drain out of the ground to the streams during the five growing months, the amounts being shown month by

[1] The reader is referred to Report on Water Supply, Geological Survey of New Jersey, 1894, and especially to pages 329 to 348, if he cares to pursue this line of study further than the present outlines.

[2] Report on Water Supply, Geological Survey of New Jersey, 1894, p. 180.

[3] Ibid., p. 336.

[4] Ibid., p. 340.

month in the first column, and the total to the end of the given month in the second column.

Flow from springs when rainfall equals evaporation.

Month.	Kattatinny Valley and highlands.		Passaic watershed.		Red sandstone plain.		Southern interior.	
	Spring flow.	Depletion.	Spring flow.	Depletion.	Spring flow.	Depletion.	Spring flow.	Depletion.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
April	1.20	1.20	1.16	1.16	1.43	1.43	1.76	1.76
May	.55	1.75	.54	1.70	.64	2.07	1.38	3.14
June	.39	2.14	.40	2.10	.45	2.52	1.30	4.44
July	.32	2.46	.33	2.43	.35	2.87	1.02	5.46
August	.27	2.73	.32	2.75	.30	3.17	.63	6.09

The second column in each case shows the water held in the interstices of the soil. The removal of this from the soil is not necessarily harmful to vegetation, but, on the contrary, is, to a certain extent, necessary, and the farmer constructs underdrains in order to get rid of it to a depth of about 3 feet from the surface, the crops being supplied mainly by the water held in the soil by capillary attraction. The amount of water which may be held in the soil in this way, however, is dependent upon the depth of the free-ground water below the surface, by which we mean the level at which water will stand in an open pit from which no water is drawn. If this ground water recedes to too low a level, the power of the soil to hold water by capillary attraction is reduced.[1] Of course it must be remembered that the above conditions of rainfall are merely hypothetical, and they never actually occur, but, as will be seen by reference to the last two tables and to the tables of summer rainfall during the dry years which we have already given, the rainfall during summer very frequently falls below the amount needed to equal evaporation. In such cases there is a still further drying of the soil by evaporation which continues persistently in its work drawing from the ground water when rainfall is not sufficient to satisfy its demands. If, on the other hand, rainfall is greater than the amount shown nature compensates for the increase and prevents the drying out of vegetation by an increased amount of drainage from the soil into the streams; that is, the water in the soil and subsoil acts just like in a sponge, the more nearly the soil is saturated the larger the amount of water which will run from it. The condition of the ground water resulting from varied conditions of rainfall will be seen, therefore, to have an important effect upon vegetation and the growth of crops.

We may get an idea of how much the ground water may be drawn down on an average in different sections of the State without injury to vegetation from what happens during the average year. Our measure of the depletion of the ground water is, in each case, the depth of rain in inches needed to refill it. The greatest depletion during the growing

[1] U. S. Dept. Agr., Weather Bureau Bul. 5, p. 25.

months is shown[1] to be, for the different regions, as follows: Kittatinny Valley and highlands, 1.23; red sandstone plain, 2.26; clay and marl district, 3.78; southern interior, 4.66 inches. These are average figures. The actual amount of depletion ranges from practically nothing on the low grounds to nearly twice these amounts on the ridges. The next table shows month by month during the driest year likely to occur (1881), the amount run off in the streams, the rainfall, the excess or deficiency of rainfall, meaning by this the amount by which the rainfall exceeds or is less than the combined evaporation and run off of streams, and last, the total deficiency of the rainfall to the end of the given month, these last amounts representing the depth of rain in inches which would be necessary to refill the ground with water.

Rainfall, evaporation; run-off, and condition of ground water during driest year, measured in inches of rainfall.

KITTATINNY VALLEY AND HIGHLANDS.

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Evaporation	0.74	0.57	0.69	0.76	0.83	2.13	3.07	2.91	2.58	1.61	1.10	0.76	17.75
Run-off	3.31	3.09	4.07	3.07	1.10	.60	.65	.27	.17	.14	.15	.20	16.82
Rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Surplus + or deficit —	......	......	......	......	—1.32	—.02	+.15	—2.22	—1.57	— .81	+1.79	+1.06	—2.94
Total deficit to end of month	......	......	......	......	1.32	1.34	1.19	3.41	4.98	5.79	4.00	2.94	......

RED SANDSTONE PLAIN.

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Evaporation	0.87	0.67	0.82	0.90	0.98	2.53	3.64	3.45	3.06	1.91	1.30	1.90	21.03
Run-off	3.18	2.99	3.94	2.93	1.30	.58	.47	.24	.16	.15	.16	.16	16.25
Rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Surplus + or deficit —	......	......	......	......	—1.67	—.40	—.24	—2.73	—2.04	—1.12	+1.59	+ .96	—5.65
Total deficit to end of month	......	......	......	......	1.67	2.07	2.31	5.04	7.08	8.20	6.61	5.65	......

CLAY AND MARL DISTRICT AND SOUTHERN INTERIOR.

	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Evaporation	0.95	0.73	0.89	0.98	1.06	2.75	3.96	3.75	3.33	2.07	1.41	0.97	22.85
Run-off	3.10	2.93	3.87	2.85	1.46	.91	.84	.46	.30	.30	.30	.30	17.62
Rainfall	4.05	3.66	4.76	3.83	.61	2.71	3.87	.96	1.18	.94	3.04	2.02	31.63
Surplus + or deficit —	......	......	......	......	—1.91	—.93	—.93	—3.25	—2.45	—1.43	+1.33	+ .75	—8.84
Total deficit to end of month	......	......	......	......	1.91	2.86	3.79	7.04	9.49	10.92	9.59	8.84	......

NOTE.—The quantities representing the total deficit at the end of a given month show how much rain or water of irrigation would be needed to refill the ground.

It will be noticed that the run-off of the streams is greater for the southern than for the northern sections of the State, the reason for this being that the soil is sandy or gravelly and contains more water in a given volume than the closer soils of the northern portion of the State, and also gives up the water more freely to the streams. We have

[1] Report on Water Supply, Geological Survey of New Jersey, 1894, p. 341.

selected in each case the best type of each section, but it must be remembered that there are minor differences for different parts of the given section—that is, parts of the Kittatinny Valley and highlands which have a large amount of sand and gravel over their surface will also show a larger run-off into the streams, and a greater lowering of ground water than is shown by the table. It will also be noticed that, while the rainfall is taken to be the same for all parts of the State, evaporation increases for the different sections because of increased temperature, and the combined effect of greater evaporation and greater drainage into the streams is a very much greater lowering of the ground water in the southern portions of the State, and this affords a still better explanation of the greater severity of droughts in those portions of the State.

The inspection of the table shows that by the end of August the following amounts of rain would be needed in this driest year to refill the ground water: Kittatinny Valley and the highlands 4.98, red sandstone plain 7.08, and clay and marl district and southern interior 9.49 inches.

It is believed to be due, to a considerable extent, to this greater lowering of the ground water that sandy and gravelly soil such as that of southern New Jersey is warmer than more retentive soils. Many phenomena connected with the growth of crops are explained by this tracing of the conditions of rainfall, evaporation, drainage to streams, and height of the ground water for different sections. An important fact to be kept in view is that the result of irrigation is to hold the level of the ground water at a more nearly constant height, and in consequence of this there will be a somewhat increased discharge of water from the subsoil to the streams. We have, consequently, to supply not merely the water demanded by the plants but this additional run-off from the soil. This increased porosity of sandy soils and readier discharge therefrom is not, however, to be regarded as an unfavorable condition to irrigation. On the contrary, it insures good drainage and prevents the presence of stagnant water in the ground in case of excessive watering, which is sometimes so hurtful to irrigated crops.

AMOUNT OF WATER NECESSARY.

Knowing that our average rainfall represents conditions very favorable to good crops, this affords a simple standard by which we can determine how much water will be necessary for irrigation in the various sections of the State, for we may safely assume that it will be the difference between the average for each section, and the lowest rainfall for the various periods as shown by table, page 29. In this table we find the lowest amount of rain from April to August is 9.33 inches, and by seasons the lowest for the spring is 5.23 inches, and for the summer, 4.62 inches. For the driest month the rainfall is only a fraction of an inch, and we may safely assume that we will have to provide

a quantity equal to 4 inches of rainfall for at least one month during certain years. This gives us the following estimate of water required:

Quantity of water required for irrigation measured in inches of rainfall.

	Driest April to August.	Driest summer.	Driest month.
Kittatinny Valley and highlands	10.42	7.73	4.00
Red sandstone plain	11.20	8.24	4.00
Clay and marl regions	11.78	8.60	4.00
Southern interior	12.34	8.95	4.00

We find, therefore, that for the whole growing season we shall have to provide in southern New Jersey practically the equivalent of 12 inches in depth of rainfall, and that our works must be so proportioned as to be able to deliver during one month the equivalent of 4 inches. The latter may be taken as the required capacity of the canals and ditches or other means of conveying the water, while the quantities in the first column represent the total amount of water which must be provided. For very much of the time this will be more than is actually needed, but irrigation works, to be satisfactory and successful, should be capable of meeting the driest possible conditions. At 4 inches per month the duty of water, as it is called, or the required rate at which the water must be furnished, is 0.55 cubic foot per second for each hundred acres. As it has been found in California, with a temperature considerably higher than that of New Jersey and a lighter rainfall, that the requirements are met by 1 cubic foot per second for each 200 acres, which is very close to the above estimate, this may be adopted as the proper average duty for southern New Jersey. We have found that the streams of southern New Jersey may be depended upon in the driest month to discharge 0.25 cubic foot per second for each square mile of catchment, and it follows that without storing water we may draw from these streams enough water to irrigate 50 acres of land for each square mile of gathering ground on the stream.

STORAGE OF WATER.

In cases where it is practicable to construct storage reservoirs to utilize the yield of the stream during the wet season for irrigation purposes a much larger area can be watered by a given stream. Our investigations in southern New Jersey show that we can always utilize 12 inches of rainfall, even in the driest year, but in order to make this amount available during the growing months from April to August we shall have to provide storage at the rate of 122,000,000 gallons for each square mile of catchment. As we need just 12 inches depth of water for irrigation purposes, it follows that with this amount of storage a stream would furnish enough water to irrigate an area equal to its catchment. The cost of storing water varies considerably with the locality, and is great for small amounts and less for works on a

large scale, but for our present purposes we may take the cost to be $150 per million gallons, making the cost of the above 122,000,000 gallons $18,300, a charge on 640 acres amounting to $28.60 per acre, which is evidently too high a cost for storage alone. To utilize 6 inches of rainfall on the catchment, we shall need 36,000,000 gallons storage for each square mile, costing $5,400, and this would serve to irrigate one-half a square mile, or 320 acres, making the cost $16.88 per acre for storage. To utilize 3 inches of rainfall on the catchment during the growing months, we shall need 17,000,000 gallons of storage for each square mile of catchment, costing $2,550, and this would irrigate 160 acres, making the cost about $16 per acre, and it will be seen that we must be prepared to expend about this amount if storage is attempted at all. The question must be decided however, for each case; consequently in making up our estimates of the ultimate capacity of various streams for irrigation purposes we have taken an area equal to the catchment of the stream.

SEEPAGE, OR RETURN WATER.

We have already seen that a considerable part of the rainfall flows off in streams, and in our table of flow from springs we find that without any additions from rainfall the soil will yield up as seepage, during the five growing months, a quantity of water equal to from 2¾ to 6 inches of rainfall in various parts of the State, the latter amount being that given up by the sandy soils of southern New Jersey. The rate at which this water is discharged depends on the amount held in the soil or the height at which the ground water is maintained, as shown by the table. Since the purpose of irrigation is to maintain ground water at a higher elevation than it would otherwise stand, it follows that the amount of this seepage or yield from springs to the streams would be increased thereby. During the average year we find[1] that the ground water is drawn upon or depleted from April to August, an average of 2.32 inches on the coast streams of southern New Jersey, whereas during the driest year it is depleted to an average of 5.82 inches. Now, if we assume that by irrigation the ground water will be maintained in the condition of an average year, the flow of seepage or spring water will be increased from that due to 5.82 inches depletion to the amount due to only 2.32 inches depletion. It has been shown[2] for the Great Egg Harbor and Batsto catchments that for any given depletion 2.32 inches depletion corresponds to a yield of 1.40 inches per month and 5.82 inches depletion to a yield of 0.8 inch per month. Therefore we have an excess amounting to 0.6 inch per month of seepage water due to irrigation on this assumption. We may check this by taking into account the yield of these southern streams for the average and the driest year.[3] From April to

[1] Report on Water Supply, Geological Survey of New Jersey, 1894, p. 341.

[2] Ibid., p. 126.

[3] Ibid., p. 266.

August this yield amounts to 8.37 inches for the average and 5 inches for the driest year, showing an excess for the average year of 3.37 inches during the five months, or 0.67 inch per month, agreeing sufficiently well with our previous estimate. It therefore appears that if we used for irrigation an amount of water equal to 12 inches of rainfall, 3 inches will be returned as seepage water, or 25 per cent of the total amount diverted from the stream. This estimate, arrived at from observations of the yield of the streams, agrees well with results obtained by some actual gauging of streams in irrigated sections of Colorado.[1]

The actual amount of seepage or return water will probably exceed this estimate somewhat, from the fact that ground water will be usually held at a little higher level, but we are disposed to think that very much increase in height would be rather detrimental to crops than otherwise. There is a tendency, where irrigation is applied, to use too much water. As we have previously stated, the drawing down of ground water to a certain extent is necessary for the proper development and perfection of the crop. Good drainage is very essential to successful irrigation. The presence of free ground water about the roots of plants prevents the proper irrigation and consequent oxidation of the elements of the soil necessary for plant growth, and it also produces a cold and late soil.

The amount of this seepage or return water should have an important bearing on the question of damages for the diversion of water in all cases where such seepage water returns to the stream from which the irrigation water has been diverted. It will almost invariably return to the same stream when the irrigated district lies within the catchment of that stream.

COST OF IRRIGATION.

The following figures given by F. H. Newell[2], pertain to the western part of the United States, where irrigation is successfully practiced.

Cost of irrigation in the western United States.

	Average for United States, per acre.	Average for California, per acre.	Average for Utah, per acre.
Cost of irrigation works	$8.15	$12.95	$10.55
Value of water rights	26.00	39.28	26.84
Annual cost	1.07	1.60	.91
Cost of bringing land under cultivation	12.12	17.48	14.85

The first figures given above represent the cost of bringing the water to the land, while the next below represent the value of such water after it has been secured, and subtracting the first from the second we

[1] Colorado Sta. Bul. 33.

[2] Report on Agriculture by Irrigation in the western part of the United States, Eleventh Census, p. 8.

find an average profit by irrigation of $17.85 per acre from enhanced value of land taken together with the water rights. The annual cost is either that of maintaining the works, or is the annual rental paid for the use of water when furnished by a corporation, while the cost of bringing land under cultivation includes clearing and leveling up to receive water. In California irrigation is applied to orchards, vineyards, small fruits, and other more valuable crops, so that the figures for that State are a better guide to us in New Jersey than the average of the whole. In the table, page 32, we showed that irrigation might easily yield an improvement of about $10 per acre in the potato crop, but we should here remark that of late years the hay crop in New Jersey has been a valuable one, and the very moderate improvement of 1 ton per acre in this crop would yield a larger return than $10 annually. Indeed, the raising of hay and forage crops by this means would be of great advantage to portions of southern New Jersey, where they are now grown with much difficulty. Taking 6 per cent on the above figures of first cost of works for California, we have for interest 78 cents, which added to the annual cost makes $2.38 annual charge per acre, to which we must add the extra labor of applying the water, or of irrigation farming over dry farming. The latter cost will depend largely on the crop, but may be averaged at about $6 a season, making a total increased cost chargeable to irrigation of $8.38 on the California basis.

As the conditions in southern New Jersey are generally favorable to low cost of irrigation by means of canals and ditches, on account of the character of the soil and the gentle and uniform slopes, there is no reason why the average cost should exceed the above estimate, and in many favorable localities it will be considerably less. Where there are valuable water powers this will add appreciably to the cost of irrigation and will make it almost impossible to carry out a profitable scheme, except it be done on a large scale. For illustration, if Maurice River should be fully utilized for irrigation it would water, without storage, 19,300 acres, and with storage about 250,000 acres. The cost of extinguishing the rights of water-power owners would probably amount to not less than $20 per acre on the smaller area and about $1.50 per acre on the larger area. This difficulty would generally be much less serious than in this case. however, although it would frequently be encountered. It must be remembered, in considering this question, that we are very conservative in our estimates as to the area which may be watered by these streams, from the fact that we have thought it well for the present not to take in consideration the large amount of the seepage water returned to the stream. Those who have followed our discussion of the irrigation water required by soils have observed that a considerable part of it is needed to make good the flow from springs which drain the water out of the soil. This water, of course, returns to the streams, and may be used over again, although we have not taken it into account.

AREAS CAPABLE OF BEING WATERED BY GRAVITY.

The following areas in southern New Jersey are capable of being brought under water and supplied by gravity through ditches and canals:

Metedeconk River in Ocean County is capable of watering 3,700 acres without and 47,000 acres with storage. All of this land, favorably located and having a soil well adapted to the purpose, may be found to the south and east of Burrsville. The water rights interfered with in this case would not be so important as to be a serious obstacle.

Toms River in Ocean County would water 8,200 acres without and 105,000 acres with storage. This water could be applied to various strips of land along the stream and its branches, although, on the whole, the topographical conditions are less favorable than on the Metedeconk.

The waters of Cedar Creek and Forked River will suffice to irrigate 3,500 acres without and 45,000 acres with storage. They could be applied to good lands in sufficient amount and favorably located between Waretown and Barnegat Park along the bay shore. Mill Creek, West Creek, and Tuckerton Creek, in Ocean and Burlington counties, will water 2,500 acres without and 32,000 acres with storage. These also could be used on good lands favorably situated near Manahawken, West Creek, and Tuckerton. Wading River is capable of watering 9,000 acres without and 115,000 acres with storage. Lands well adapted for the purpose are found about New Gretna, Harrisville, and Green Bank, with some smaller areas along the upper stream and its branches.

Mullica River above Batsto will furnish sufficient water to irrigate 11,000 acres without and 140,000 acres with storage. The watershed of this stream is almost level in a direction almost transverse to the course of the streams, and slopes with the streams at the rate of about 5 feet to the mile. A large area of sandy land could easily be brought under water lying between Batsto, Hammonton, and Atsion. This land is at present mainly waste land.

Great Egg Harbor River will furnish water for 15,000 acres without and 192,000 acres with storage. The water could be used on a belt of land along the stream between New Germany and Mays Landing, most of which is wild land; also on a strip along each bank below Mays Landing, that along the west bank between the highway from Mays Landing to Tuckahoe and the salt marsh being quite favorable for the purpose, and including some areas now under cultivation. An important water power at Mays Landing would be affected by any extensive irrigation works, but along the west bank between Mays Landing and Tuckahoe considerable development could be made by utilizing South River and Stephens Creek without affecting any valuable water power. The same is true of Babcocks Creek at Mays Landing.

Tuckahoe River is sufficient to water 2,500 acres without and 32,000 acres with storage, and land well adapted for the purpose, a consider-

able part being already under cultivation, is found along both banks of the river between Hunters Mill and Tuckahoe.

The streams of Cape May County are not adapted for gravity irrigation except in a limited way. Manumuskin and Manantico creeks would together furnish water for 3,500 acres without and 44,000 acres with storage. They could easily be made to water all of the land between the West Jersey Railroad and Maurice River, extending from Millville to Port Elizabeth, and Manantico Creek, especially, affords an opportunity for an irrigation development on a considerable scale without interfering with any water rights, all the mills on the stream being now abandoned.

Maurice River above Mays Landing is capable of watering about 11,000 acres without and 170,000 acres with storage. The water would have to be applied to lands lying along both banks of the river and its branches, and generally not more than 30 feet higher than the stream. Not much of this land is now under cultivation, although there is some on the west branch between Union Grove and Bradway.

On the Atlantic coast of southern New Jersey the above-mentioned streams offer good facilities for irrigation by gravity, but the streams on the Delaware slope of the State do not present such favorable topographical conditions. For the most part these streams run at low level through ravines with flat bottoms and rather steep banks, so that the water could only be brought out on the neighboring lands by means of low canals from points so high on the streams that the drainage area is small and insufficient to furnish any large amount of water. This country along the lower Delaware, however, contains some fertile lands, and it is the region of the lightest rainfall and severest droughts in the State; consequently it is probable that nowhere else would irrigation be more profitable.

Cohansey Creek above Bridgeton would water 2,250 acres without and 28,000 acres with storage, but the topographical conditions are very unfavorable for gravity systems. We shall see later how the waters of this creek may be used advantageously by pumping. Salem Creek, at Sharptown, if diverted at about 50 feet elevation, could be made to water 1,000 acres without and 14,000 acres with storage. This water could be used profitably on fertile lands now under cultivation in Upper Penns Neck and the west part of Mannington Township.

Alloways, Oldmans, Raccoon, Timber, and Coopers creeks are open to the objections which we have pointed out as peculiar to streams of the Delaware slope, and are not well adapted for gravity systems of irrigation.

Rancocas Creek above the forks will water 15,000 acres without and 192.000 acres with storage, but there is a considerable amount of valuable water power which would be affected. The water could be applied to land distributed along the stream in Pemberton, Lumberton, East Hampton, and South Hampton townships, Burlington County, most of these lands being now under cultivation.

Crosswicks Creek is not well adapted to a gravity system of irrigation.

Some 5,000 acres of level gravelly lands east and northeast of Trenton, and under 60 feet elevation, could be watered by the head waters of Assanpink Creek.

This brief review of the possibilities of gravity irrigation in southern New Jersey shows us that 75,000 acres can readily be watered without the use of storage reservoirs, and over 900,000 acres if the streams are fully utilized by storage. We have seen, however, that the cost of such storage would scarcely be warranted, but we may consider that the watering of 250,000 acres of the areas which we have indicated is entirely practicable. Most of this land is on the Atlantic Slope, and very little of it is now under cultivation. Exclusive of storage charges, it could generally be irrigated at a cost within the figures already given for California, or, say, within an annual charge of $8 per acre. If this area could be successfully brought under cultivation by this means it would add 10 per cent to the total cultivated area of the State, and probably from 20 to 25 per cent to the value of its agricultural products. Several of the districts mentioned offer excellent opportunities for a beginning on comparatively a small scale, and in such a manner that ultimately the development could be extended to the full capacity of the stream. We must recognize the fact that the benefits to be derived from irrigation must first be demonstrated by works on a limited scale, although the highest efficiency and the largest amount of profit will be realized by a large scale of development. Generally the soil of these tracts, and the configuration of the surface are very favorable to the purpose, and a large part of the land could be acquired at a low cost. The conditions are peculiarly favorable for market gardening and the raising of fruit.

In the northern part of the State the need of irrigation is sometimes felt quite severely on the red sandstone plain, but to a much less extent in the Kittatinny Valley and highlands. The water could almost always be applied on this part of the State by gravity, but water rights are more valuable here, so that it is scarcely probable that irrigation will be extensively adopted for general farming, although it may be for special crops.

We shall not undertake for the present to extend our mention of these specific cases suitable for gravity systems of irrigation into northern New Jersey. There are, however, quite a number of cases where irrigation could be used profitably in these portions of the State. Considerable areas, such as Pompton Plains and other fertile portions of the Passaic Valley offer facilities for such improvement.

IRRIGATION BY PUMPING.

While irrigation by gravity through canals and ditches is a simple and well-tried method and one which usually gives a low operating cost,

there are many cases in New Jersey where the water could be advantageously pumped. There are large fertile areas in Salem and Gloucester counties which can not be watered by gravity, but which are traversed by numerous creeks, where an abundant supply of water can be obtained at all times. The whole area is also bordered by the Delaware River, the water of which, down to the head of the bay, is usually fresh enough to be used for this purpose. A considerable area of good land along the east shore of Delaware Bay and south of Cohansey Creek is similarly situated. Then, again, in many cases the cost of extinguishing water rights would be eliminated by pumping from the lower parts of the streams, and the saving thus effected might fully compensate for the cost of pumping, not to speak of the saving in construction of long main canals. Pumping could be applied in the districts which we have mentioned, either to raise the water into canals and ditches, to be distributed by the ordinary method, in which case pumping would be done inexpensively by centrifugal pumps; or force pumps could be used and the water distributed under pressure through a network of pipes to be laid over the district to be irrigated, the water being applied by means of hose from a number of conveniently situated hose plugs. At first sight this seems an expensive method, but it bears the test of careful estimate, and has very great advantages where it is important to economize water or to distribute it readily and conveniently, as would be the case where irrigation is employed in market gardening and in orchards. We have taken for the purpose of an estimate an area of 640 acres, or, say, 32 garden plats of 20 acres each, the water being pumped from a stream and distributed by means of pipes, as we have suggested. We find that for such a tract of land a plant of the best character could be installed for $45,000, or about $70 per acre. We also estimate that, allowing on this sum 6 per cent interest and 3 per cent for depreciations, all expenses of operation, including the watering during a season of one hundred days, would not exceed $15 per acre. We believe that good returns could be had from this outlay in any of the districts which we have mentioned as favorable to the application of this system. The cost of this system per acre would increase with smaller plats than 640 acres, and would decrease if applied on a larger scale. It is probable, however, that by the use of small pumps operated by gasoline engines, which could be operated without the constant attendance of an engineer, the system could be profitably applied without much increase of cost to a single ordinary farm. For smaller plants, however, such as are likely to be adopted experimentally during the early attempts at irrigation in the State, it is probable that a windmill pumping to a tank, either from a well or stream, the water to be distributed from the tank by pipes, would be the most practicable system.

We shall leave the consideration of this question of limited or experimental plants for consideration in a later paragraph (p. 48).

AREAS ADAPTED TO IRRIGATION BY PUMPING.

The following areas are conspicuously adapted for such an extended system of irrigation by pumping as we have estimated upon, while they are not favorably situated to be watered by gravity. In Cumberland County, south of Cohansey Creek and west of the Cumberland and Maurice River Railroad, near Fairton and Cedarville, some 16,000 acres could be thus irrigated. The water for this purpose could be obtained from Cohansey Creek. The soil is good, and most of this district is now under cultivation. Some 500 or 600 acres between Cohansey and Stow creeks in the same county could be watered partially by pumping and partially by gravity. The whole of the western portion of Salem County, extending 6 miles or more back from the Delaware River and including some 80,000 acres of fertile land, most of which is now under cultivation, is well adapted for irrigation by this method. In Gloucester County about 40,000 acres along the Delaware and its branches could be watered. In Camden County about 12,000 acres, and in Burlington County 25,000 acres are suitable for this treatment. There is also some land between Red Bank and Colts Neck, in Monmouth County, which could be watered from Swimming River. A total of at least 175,000 acres of good land, mostly under cultivation, in the counties named, is adapted for irrigation by pumping either into irrigation canals in the more usual way, or into pressure pipes, as we have suggested. Most of this land lies convenient to tidal creeks and rivers whose waters are fresh or only slightly brackish. The waters of many of these creeks also carry a very considerable amount of rich sediment, and would undoubtedly have a marked fertilizing tendency.

IRRIGATION BY WELLS.

As is now well known, southern New Jersey affords an excellent field for obtaining water supply from tube wells. An examination of a considerable number of wells indicates that it is fair to expect from a 6-inch well, from 100 to 200 feet deep, a yield of 25,000 gallons daily, or sufficient to irrigate 10 acres of land. This is purposely conservative, and we are well aware that there are a number of wells which would be ample for 20 acres. Of course this method of irrigation means that we must pump by windmill or other power, and in order to use the water economically it should be applied by pipe distribution under pressure. This well water may have the disadvantage of a lower temperature, which could be partially remedied by storing in a tank, and may not have all the fertilizing properties of stream water, but the method allows the entire plant to be confined to the limits of a small farm without risk of damage to water rights or otherwise. There are also many cases where a number of small driven wells of moderate depth, say 15 or 20 feet, would answer the purpose better than tube wells. It is impossible to make any estimate of how much land may be irrigated in this way, but the aggregate may be large.

WARPING.

This process, which properly comes under the head of irrigation, is applicable to tidal meadows which have been reclaimed, and is a process not unknown in Cumberland and Salem counties, where it has been practiced to a certain extent for many years. It is a well-known fact that tidal meadows which have been embanked and improved generally shrink or settle to a level considerably below the level of high tide. Some of the older embanked meadows in the State range from 2 to 4½ feet lower than high-tide level. This gives an opportunity for the application of warping, which consists in letting the water flow in upon the embanked land to deposit its sediment. The system has been carried to a high degree of perfection in some portions of England, where the works are of a substantial character and the water is controlled by permanent sluices. In our own State the process is often effected by simply cutting the banks, which does not leave the farmer a proper control of the water. The purpose to be kept in view in this method of irrigation is to secure the best and largest part of the sediment contained in the water as a deposit upon the land, and the flowing and running off of the water must be so controlled that the volume of mud deposit has an opportunity to dry between tides. The result, when properly conducted, is to secure to the land under treatment a new soil, and the accumulation of sediment is much more rapid than would commonly be supposed. Ordinarily one year will suffice to entirely renew the soil of such a tract. The area of tidal meadow which has been reclaimed in Gloucester, Salem, and Cumberland counties amounts to about 26,000 acres. In the past the cultivation of these tracts has been very profitable, but during recent years there has been a tendency to neglect them somewhat, a fact which is partly due to the low prices of agricultural products; but while the very large returns of the past may not be again obtained, it is worth while to consider whether, even under present conditions, a good profit is not possible in cultivating these meadows, and whether a careful application of the warping process would not be a means to this end.

WATER MEADOWS.

While the application of irrigation will probably be most sought by the market gardeners and producers of small fruits, it seems worth while, in view of the general scarcity of hay and pasturage in southern New Jersey, to call attention to the possibilities of irrigation in producing hay and forage crops. The application of irrigation to water meadows in England is well known, and the results seem to have been highly satisfactory. The method of applying the water does not differ materially from ditch and bed work irrigation for other purposes, but the water is mainly applied through the winter months in England, although to a less extent throughout the year. It is so applied as to

protect the grass from the effects of early and late frosts, thus giving it an opportunity to start much earlier in the spring. It has been found possible to produce on each acre one month's grazing for from thirty to forty head of sheep in the spring, and after that 2 or more tons of hay has been cut, or when used for grazing alone the same number of sheep has been fed throughout the season. This is sufficient indication of the possibilities of irrigation for this purpose, and there seems no good reason to doubt that on the low-lying lands of southern New Jersey as good results as this could be obtained. The expense of watering such meadows is comparatively light, but the amount of water used is rather large. However, since the water is used largely during the months when it is not employed for irrigating ordinary crops the large amount needed would not be any great objection, and the irrigation of meadows could well form a part of a general system of irrigation.

TOTAL AREA IRRIGABLE.

If we consider only the available water supply, we find that even in the driest year which we have experienced enough water has run to waste in the streams to furnish an ample supply to irrigate the entire area of the State. Considering only the areas in southern New Jersey which we have pointed out as peculiarly well adapted to development at a reasonable cost, we find that, neglecting what may be watered by wells, fully 325,000 acres may be brought under water, and this alone, if well managed, would probably increase the value of the agricultural products of the State not less than 30 per cent.

ESTIMATED COST OF IRRIGATION AND SUGGESTIONS FOR SMALL PLANTS.

Our estimate of duty of 1 cubic foot per second for each 200 acres amounts to 3,236 gallons daily per acre during the month of maximum requirement. With a pipe distribution the economy of water would be such that this would probably be reduced to 2,500 gallons daily per acre. Our maximum monthly requirement was estimated at 4 inches per month, and if we assume that by pipe distribution this may be reduced to 3 inches, and let this be divided into four waterings, we shall need three-fourths of an inch for each watering, or practically 20,000 gallons per acre. Let us assume that we wish to water an area of 10 acres requiring 200,000 gallons for each watering. We estimate in all sixteen waterings for the season, and for the driest month we shall need one watering each week. If we apply this water in six days, we shall need all of the time of one man during this month, and ninety-six days of his time during the season of maximum requirement. If we arrange our plant so that the watering may be accomplished in three days, the driest season will require forty-eight days in all for the watering and 66,000 gallons daily. This is probably a good basis on which to work, because there will be many years when only a fraction of this amount

of time will be consumed, and, indeed, the maximum requirement will only occur at long intervals. At ten hours daily we must be able to distribute 6,600 gallons hourly from any hose plug in the plant, and this determines the capacity of our pipes and pumping engines.

It is evident that for a plant of this size, if we must depend on windmills, we should have tanks at hand to store at least one day's requirement, or 66,000 gallons. Assuming that our 10 acres is square, with a well driven at the center, and pumping by windmills to tanks, we estimate that the entire cost of installing the plant will be $4,500, or about $450 per acre. Of course, the operating expenses of such a plant will be light, as nothing is required for fuel and the operation of the pumps. This provides for an ample plant, but if one chooses to take some chances on the extreme dry years a lighter plant will suffice, and the cost may be cut down even as low as $2,500 and still give works of fair efficiency, which may once in twenty-five years during an extremely dry season require all of one man's time to do the watering. In this plant we have adopted 4-inch galvanized, lap-welded wrought-iron pipe for the distribution, and so disposed that the maximum distance from a hose plug to any part of the tract is 110 feet. About 100 feet of 2-inch hose would consequently be required.

If we substitute for the windmill a gasoline vapor engine of sufficient capacity to deliver 6,600 gallons hourly, we may do away with the storage tanks, provided that our well is of sufficient capacity to yield this amount of water. Of course, this will deliver the water at a lower temperature. The cost of such a plant will be about $1,000 less, or $3,500. This would probably also be reduced to $2,500 by adopting a lighter plant, say one capable of delivering 3,300 gallons hourly. Such a plant would have 3-inch pipe instead of 4-inch, as well as a lighter engine, and since during the driest weather its deficiency could be made good by simply taking more time to do the watering it is probable that this reduction would be a wise economy. In case this plant should draw from a stream instead of a well the cost would not be materially different in case the stream was not more distant than about 500 feet from the tract to be watered. The gasoline engine is to be preferred to the windmill because of its greater reliability. The cost of operation is light, as the engine needs very little attendance, the cost of fuel for the lighter engine amounting to about 50 cents daily.

There are also probably a number of localities near some existing or abandoned mill site where water power could be utilized cheaply for pumping, thus offering favorable conditions for a test of irrigation.

If we wish to adopt a gravity system for our test it will usually be advisable to construct works sufficient to bring about 100 acres under water, and even to do this it will generally be economy to select a site favorable to further extension and begin our works on a plan adapted to such extension. Thus a ditch 7 feet wide on top, 2 feet at bottom, and 2½ feet deep can be constructed in many parts of southern New

Jersey at a cost not exceeding 12 cents per foot. Such a ditch with a fall of 1 foot in 2,500 will deliver 20 cubic feet a second, or enough water to supply 4,000 acres of land. If a favorable location is selected, either where there already exists an abandoned milldam which can be repaired or where the site is favorable to a small dam at low cost, a mile of canal and a dam may be constructed at a cost not exceeding $1,100, and 100 acres could be brought under water. The cost would, therefore, be $11 per acre, which is not excessive. This will enable a thoroughly satisfactory trial to be made, and such works could be gradually extended until the entire cost for dam, canals, and main ditches would not exceed about $5 per acre. The economy of large-scale works by the gravity system is very marked, but it will be seen that if a start is made under such conditions as we have supposed the cost of a small development need not be excessive, while if successful the prospects are excellent for a large profit in the ultimate extension of the works. Newell's figures (p. 40) show that, taking the average over the whole United States, the rental value of this water thus brought to the land would amount to $1.07 per acre, while in California it amounts to $1.60. Many instances might be quoted where a much higher rental has been paid, but these figures are sufficient to suggest the handsome return possible from such a plant. It is impossible for us to enumerate at present all the points at which such a development could be reached under favorable conditions, but among others we have in mind Hunter's mill pond, to be used for the lands along the north bank of the Tuckahoe River; Cumberland Pond on Manumuskin Creek, to be applied along the west bank of the creek; the pond at Bamber and Cedar creeks in Ocean County; the mill pond on Kettle Creek at Silverton, where there is probably not more than enough water, however, for about 400 acres. Conditions are generally less favorable for such a plant on the Delaware slope, for reasons which we have already pointed out. Still they may be found on examination.

USE OF IRRIGATION IN NEW JERSEY—METHODS AND RESULTS.

More or less complete data on the above points were secured from five irrigation plants, three located in Gloucester, one in Cumberland, and one in Hunterdon County. Three of these have been in operation from two to twelve years, have given eminent satisfaction, and illustrate the practicability and usefulness of irrigation for small fruits and vegetables, especially on limited areas.

IRRIGATION ON THE FARM OF JOHN REPP, GLASSBORO, GLOUCESTER COUNTY.

Mr. Repp's fruit farm of 100 acres is located near Glassboro, Gloucester County, upon which is grown a great variety of fruit, peaches, apples, berries, grapes, etc., while a considerable portion of the land is devoted to market gardening while being prepared for fruit crops. Mr. Repp irrigated from 2½ to 3 acres since 1884, and is about to increase largely his operations in this direction. He has found that during two

years out of three there will be dry spells, when it will pay to irrigate the crops with which he has experimented.

Character of soil and method of manuring.—The land that has been irrigated during the last twelve years by Mr. Repp is a sandy loam underlaid by a clayey subsoil. It had been heavily manured with New York stable manure and fertilizers before being irrigated, and has been manured every year since 1884 in the same way until 1892. Since 1892 chemical fertilizers have been used alone before planting. He still uses the manure in the fall as a mulch.

The irrigation plant.—The accompanying outline shows the position of the land, 5½ acres, upon which irrigation has been practiced and the location of the reservoir, pump, and pipes in reference thereto.

A shows the shape of the pond, which covers about one-half an acre.

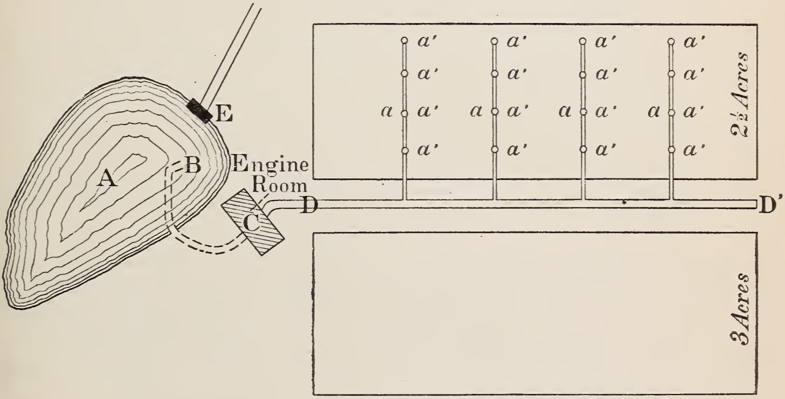

FIG. 3.—Irrigation system on the farm of John Repp, Glassboro, N. J.

The water backs up into the swampy land where the springs are located, and is about 4 feet deep near the dam.

The pipe that carries the water to the pump opens near the surface of the pond, several feet from the bank. The water enters the pipe through a strainer.

C represents the position of the engine house, or pumping station. This is a small, substantial structure, built to cover and protect the steam pump and boiler, which fill the available space therein.

At D D′ is shown the position of the underground main pipe, 1½ inches inside diameter, leading from the pump to the field to be irrigated, which is divided into two nearly equal parts by this main pipe. On one side is 3 acres, on the other 2½ acres. The side pipes *a a a a*, ¼ inch inside diameter, are laid under ground at distances of 10 feet. These pipes are furnished with faucets *a′ a′ a′ a′* for attaching rubber hose.

Irrigation of strawberries.—Mr. Repp describes his actual operations in watering or irrigating a field of strawberries as follows:

About ten years ago I built a dam across a small stream, fed by springs, that runs through my place, and inclosed about one-half an acre of water, 3 to 4 feet deep.

The land I wanted to irrigate is from 4 to 10 feet above the water. I first thought I would get a windmill and pump the water into a reservoir, but I found it would take 800 barrels of water to cover 1 acre an inch deep, and as I wanted to grow about 3 acres, in time of drought it would be necessary to put on not less than 1 inch of water twice a week, thus, in my judgment, rendering the storage scheme too expensive; so I put in a steam pump which, with an 8-horsepower boiler, will raise 800 to 1,000 barrels a day. The cost of the entire plant, including pipe and hose, was $600.

I laid off my land in two blocks, 2½ acres in one and 3 acres in the other. Between the blocks I laid a 1½-inch pipe under the ground. I have one of the blocks in berries each year. In planting, get ground fine and level, mark out with hand marker every other row 20 inches, every other 28 inches, plant 1 foot in row, cultivate and hoe. In hoeing, the man walks in the wide row; by so doing leaves the ground a little lower between the narrow rows. In August stop cultivating between the narrow rows, let them fill up with runners, and keep the wide rows cultivated till fall. Before winter sets in cover the beds with horse manure, about a carload to the acre. In early spring rake the manure in wide rows, cover the manure with salt hay, using 1 ton per acre. The 1st of May put on 800 pounds per acre of a good fertilizer.

As soon as it gets dry, start the pump. I run the rows at right angles to the main pipe, laying three-fourth-inch pipe 10 feet apart, parallel with the rows, have spigots about 60 feet apart on the small pipe, and connect with three-fourth-inch hose 50 feet long. A man changes the hose from row to row, running the water down the row. The longest period that I have been obliged to use the pump in any one year was nineteen days. My expenses for two men, fuel, and wear of the plant are about $3.50 per day.

Cost of irrigation.—The first cost of a plant similar to the one operated by Mr. Repp would be considerably less now than in 1884, the year when he started. Windmills have been improved since that time, and now less expensive gasoline engines are also entirely practicable for this work. Mr. Repp estimates the original cost of his entire plant at $600, the chief items of which are—

Worthington steam pump	$190
Steam boiler	150
400 feet rubber hose	40

The main iron pipe, connections, shed, stopcocks, etc., make up the balance of the initial cost.

Celery after strawberries.—As soon as the first crop of strawberries is gathered the vines are plowed under; that is, one summer is spent in preparing for the crop which is gathered the following spring. The patch is plowed in season to allow for the growing of another crop of some kind during the summer and fall. During the first years of the enterprise this second crop was celery. Celery was grown very successfully by irrigation, but it was difficult to keep for the winter market.

When setting out the celery plants in a dry time, shallow furrows were wetted before planting. After setting out, irrigation is accomplished by turning a furrow away from each side of the row and running water down these furrows. When the water has soaked in the furrow is turned back.

Lettuce after strawberries.—Mr. Repp's first attempt to irrigate lettuce was made in the extremely dry summer of 1895. The experiment was not a financial success on account of many hindrances at the start. The seed was sown about August 1 in drills. The seed proved to be poor and the field was replanted about August 15. Irrigation was effected by sprinkling with hose, very much in the same way that lawns are watered. The whole field of $1\frac{3}{4}$ acres was thoroughly wetted by four men in half a day. This watering was repeated twice a week until the lettuce was well started. There was no rain for three or four weeks after the seed was sown, but the waterings were sufficient to produce a good crop, though reduced in value by cold weather before it was ready for market.

It will be readily seen that the amount of water used on the lettuce was very small as compared with that used in watering strawberries. Full-grown strawberry vines will give off a great deal of water through the leaves on a hot day. The water that is transpired would be especially large from a field of strawberries grown as Mr. Repp grows them, where nearly half the field is thickly covered with thrifty vines.

During the ripening and picking season of strawberries, it will be remembered that on the field in question 200 tons of water are spread over an acre in a week (when no rain falls).

The amount of water used per acre on lettuce can be calculated approximately from the capacity of the steam pump. This will pump about 40 gallons of water a minute when the water is raised 7 feet, as in this instance. One-half day equals three hundred minutes. $300 \times 40 = 12,000$ gallons. This quantity was used on $1\frac{3}{4}$ acres twice a week. Twenty-four thousand gallons on $1\frac{3}{4}$ acres is 55 tons of water per acre once a week.

Irrigation of onions.—Mr. Repp has also irrigated onions, though his experience with this crop was less successful than with the others. He was unable to prevent blistering. Doubtless further study and experience will enable him to handle the water for this crop in a satisfactory manner.

Profits from irrigation.—Mr. Repp, having irrigated since 1884, is competent to give a very correct opinion concerning the average profits of irrigation with some crops.

For some years the $5\frac{1}{2}$ acres under irrigation were devoted to growing strawberries and celery. One-half was irrigated and cropped each year. During the alternate years the land was devoted solely to the first year's growth of strawberry plants without irrigation. Immediately after the berry crop is removed the vines are plowed under, and about the middle of August the celery plants are put out.

Mr. Repp has irrigated strawberries, on the average, two seasons out of three since 1884. His smallest gross sales for any season in which irrigation was practiced were \$300 per acre; average yearly gross sales of strawberries for twelve years from the $5\frac{1}{2}$ acres were \$250 per acre.

It should be borne in mind that only half the area ($2\frac{1}{2}$ acres one year, 3 acres the next) bore a crop each year. The average gross sales for bearing years were $500 per acre.

In addition to the profits from strawberries, were the profits from the celery, lettuce, etc., grown on the same land.

IRRIGATION ON THE FARM OF T. H. WHITNEY, GLASSBORO, GLOUCESTER COUNTY.

Pumping water for irrigation by water power.—In 1894 Mr. Whitney erected a plant to irrigate by water power several acres of land on one of his many farms about Glassboro.

Although the plant has not yet been used, because of a change in ownership, the arrangements are practical and provide for irrigation at a small expense, both initial and for operating. The construction and cost of the plant are the chief points considered. The accompanying sketch shows the locations, respectively, of the reservoir, dam, water wheel, pipes, etc.

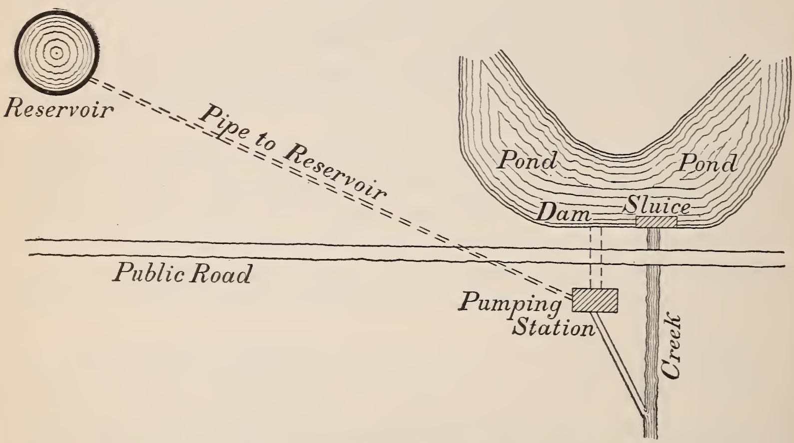

FIG. 4.—Irrigation plant on the farm of T. H. Whitney, Glassboro, N. J.

The pond on Mr. Whitney's farm covers about $3\frac{1}{2}$ acres, and is supplied by two creeks, or rather several springs, since the pond extends nearly to the source of both creeks. These springs furnish a very steady supply of water. A large volume of water was flowing over the dam in December, 1895, while springs and creeks were drying up all over southern New Jersey on account of the prevailing drought. The dam is about 10 rods long. The water falls 9 feet at the sluice, and this fall is secured by backing the water only 300 or 400 yards up the stream.

The water passes through a large conduit from the pond under the road to the top of the 8-foot overshot water wheel. This water wheel is connected by cogged wheels to a Worthington double-action pump. The waste water then passes through a ditch to the main creek channel. The water for the reservoir is pumped through an underground clay

pipe, 2 inches in diameter. The reservoir is a bowl-shaped excavation, the bottom and sides being thickly cemented. The dimensions are, approximately, 9 feet in depth. Bottom circumference, 55 feet; top circumference, 125 feet; it has a capacity of over 50,000 gallons, and is located on a hill 40 feet above the level of the water in the pond.

The system is evidently less expensive than one in which steam power is used. The first cost need not be so great if the farmer uses his odd time to build the dam, lay the pipes, etc. And the running expenses consist mainly in the wages of the men who apply the water to the land, no engineer being required.

The number of farms where water power can be used in southern New Jersey is, however, small, since the average fall in creeks is but 8 or 10 feet per mile; in the northern sections of the State this method could be used in many places. The farmer owning 10 to 20 acres could not use water power in many cases. On large farms or in localities where several small owners could and would cooperate it would appear that water power could be used to advantage to pump for irrigation purposes.

Subirrigation.—Subirrigation is also practiced on Mr. Whitney's farms at Glassboro, and his method is quite unique, though there is probably very little land that can be irrigated in this way in the State.

A certain area of comparatively low land, underlaid with drain tile, became very dry during long droughts; to remedy this, a dam was built immediately below the point where the drain outlets into the creek, and the process of drainage was reversed. That is, the water of the creek was forced back into the drain tile, and out through the interstices into the soil, so that the latter was rendered moist within a few inches of the surface.

Mr. H. D. Chew, manager of Mr. Whitney's farms, has successfully irrigated onions and strawberries by this method.

IRRIGATION ON THE FARM OF JOSIAH H. SHUTE, PITMAN GROVE, GLOUCESTER COUNTY.

Garden irrigation.—Mr. Shute's outfit consists of an 8-foot iron turbine windmill set up on a 30-foot tower; two tanks of 500 and 2,000 gallons capacity, respectively; a Buckeye double-action force pump; piping from the pump to the tanks and irrigated field, and hose for distribution of water over the field. With a storage capacity of only 2,500 gallons, Mr. Shute successfully irrigated a little over 1 acre during the season of 1895, selling therefrom $250 worth of products, and having beside a plentiful supply of vegetables, etc., for family use.

The diagram (p. 56) will show the arrangement of his plant.

The dotted lines represent the underground pipes. The windmill and pump supply the house and barn with water, as well as the garden. The small tank is in the attic of the house, about 20 feet above the ground. All the water is pumped into this tank, which, when nearly full, discharges through the full length of pipe into the larger tank.

The 2,000-gallon tank is on the second floor of the barn. This almost constant flow of water through the pipes under the irrigated field has kept them clean.

Pipes furnished with faucets come up some distance above ground at four places along the main line, to which hose is attached long enough so that any part of the field may be watered.

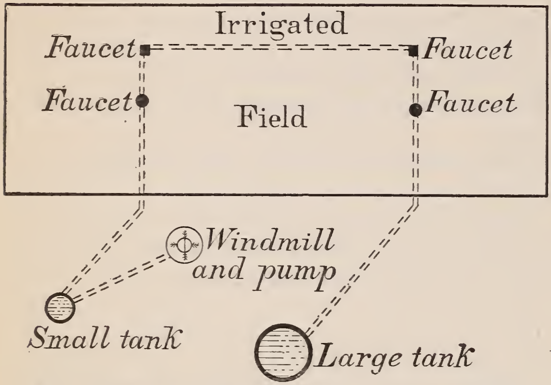

Fig. 5.—Irrigation system on the farm of J. H. Shute, Pitman Grove, N. J.

Crops irrigated.—Mr. Shute's specialty has been the growing of a crop of onions and celery on the same land in one season, and helping both crops by irrigation. He puts out his onion sets as early in the spring as possible, 1 foot by 3 inches. If there is dry weather while the onions are growing, he irrigates by sprinkling, or by flooding. Onions should be watered early in the morning, in the evening, or on a cloudy day. The onions are harvested early in July. Some are pulled early and sold in bunches with the tops on. While the onions are growing, the celery plants, White Plume variety, have been helped by watering, and about the middle of July are ready to transplant. These plants are set out 6 inches by 3 feet, the ground about them being thoroughly wetted. Other varieties would need to be 4 or 5 feet apart.

Mr. Shute irrigates his celery once in ten days, or two weeks. This operation is similar to Mr. Repp's method of irrigation of celery, already described. Mr. Shute has irrigated on a smaller scale, strawberries, lima beans, and other garden produce.

Cost of plant.—The chief items of expense in preparing for irrigation are as follows:

Iron turbine windmill and tower, not set up	$75.00
Double-action force pump	8.00
500-gallon tank	18.00
2,000-gallon tank	35.00
450 feet three-quarter-inch pipe, 4½ cents per foot	20.25
Total	156.25

The drive well from which the water is secured is not included in the cost of the plant, as it was put down primarily to supply the house and barn.

IRRIGATION ON THE FARM OF A. P. ARNOLD, VINELAND, CUMBERLAND COUNTY.

Mr. Arnold's windmill and reservoir located on the top of a hill were put up for other purposes than irrigation, the latter being incidental only.

The advantages for irrigation accruing from the location of the reservoir are apparent. After the water is in the reservoir, the whole farm can be irrigated without further use of power; and in case sufficient water can be secured from the well water rights might be sold to neighbors.

The soil on this farm is very sandy, with sandy subsoil, and, while perhaps requiring more frequent watering, is liable to suffer more from drought than a soil of greater water-holding capacity, hence benefits from irrigation are likely to be quite as great.

The reservoir is both strong and handsome. It would probably not be necessary to expend so much money on a reservoir for irrigation purposes only. However, there is very little chance of the walls of this reservoir cracking on account of the outward pressure of the water and letting the water soak out into the sandy soil.

The well was never lacking in water, although the summer and fall of 1895 were the driest known in Vineland for many years. The drive well is 70 feet deep, and it is about 35 feet to the water level. The water for irrigation purposes can be drawn from the reservoir through a pipe connected with the lowest part of the bottom and opening some distance down the hill.

Construction of reservoir.—The reservoir is approximately 45 by 90 feet in area; it is very shallow at one end, and gradually deepens until it is 7 feet deep at the other end, where the outlet pipe is connected.

The sides are built of stone and rise about 2 feet above the surface of the ground. The bottom and sides are thoroughly cemented.

Cost of the reservoir, windmill, and waterworks.—The cost as reckoned below does not include the wages for the labor that any farmer or his help can do at odd times.

Total cost of windmill set up, and waterworks for house and barn..	$120
Cost of reservoir......	130

There will be some further work and expense before everything is finished. A reservoir for irrigation purposes only should cost much less money. Probably $50 would buy all the material needed for a reservoir of much greater capacity, and a 12-foot windmill set up merely for the purpose of pumping water into the reservoir would cost much less than $120. There would be an expense not mentioned in the above estimate, viz, the cost of piping to the fields to be irrigated; and a larger windmill would be required if several acres were to be irrigated.

If large, tight reservoirs are provided, wind power may be made available for irrigation on a fairly large scale in southern New Jersey.

During summer droughts there is apt to be very little wind, so that

at the critical time, when large quantities of water are needed, there is very little available where wind power is the sole dependence, unless it has been pumped into reservoirs which are high enough above the land to be irrigated to permit the water to be distributed by gravity upon the land where it is needed.

IRRIGATION ON THE FARM OF THOMAS R. HUNT, LAMBERTVILLE, HUNTERDON COUNTY.

Mr. Hunt's place is located about 1 mile from the Delaware River, southeast from the town; the land is what is known in that section as "mountain soil;" it is a medium clay loam, and with a rather compact clayey subsoil. It retains moisture only reasonably well in dry weather; it is fairly well adapted for asparagus, celery, onions, and for the small fruits, raspberries and strawberries.

Mr. Hunt has used irrigation successfully for a number of years. Previous to 1892 he obtained his water from the waterworks supplying the town of Lambertville. In 1892 he put in his own plant, which consists of a Regan vapor engine, and the necessary mains. The engine is placed immediately upon the bank of a pond, which was built many years ago for the purpose of supplying water for general use. From the engine house he carries his main, a 2-inch pipe, directly west about 350 feet, where it reaches an elevation about 20 feet above the level of the pond, and is high enough to permit of his carrying water by gravity to any part of the farm which he desires to irrigate; about 100 feet from the engine house he carries a branch main of the same size about 200 feet south, in which T's are placed every 50 feet for hose connections; a 1-inch pipe is carried about 150 feet north to his garden, where a large portion of his plants are grown. From the westerly point he carries a 2-inch iron pipe main, arranged for connection in the same manner, about 200 feet north across the public highway. From this point the water is carried by means of fire hose for several hundred feet east and west connected with T's every 50 feet. The area capable of being watered under present circumstances is about 10 acres. The crops which have been irrigated up to the present time are strawberries, early cabbage, and celery, though the crops which he grows, and which may be irrigated by his system, consist of 2½ acres of strawberries, 3 acres of raspberries, 1½ acres of onions, 2 acres of celery, 2 acres of asparagus, and three-fourths to an acre of early cabbage. The variety of crops grown permits him to distribute his water over a larger area than if the entire area was in one or two crops.

The accompanying diagram (p. 59) gives a very good idea of the situation of the plant, and is described somewhat in detail, since it is representative of a large number of locations in the northern section of the State.

A represents the pond, which covers about half an acre, and is supplied by a stream large enough to meet all demands for irrigation. B is the engine house; C, C, C, C shows the location and direction of the mains, and D the 1-inch pipe running to the garden; E is the westerly

point of the main at which a T is placed; it has an elevation of about 20 feet above the level of the pond; at F is attached the fire hose, which may be carried several hundred feet, both west and east of the main. The areas showing asparagus and onions, south of the main pipe, slope toward the pond; the asparagus may be irrigated by attaching the fire hose at E. The area showing asparagus, peas, onions, and strawberries slopes so that it may be irrigated in two directions. The area to the north is quite irregular but is capable of irrigation mainly in the one direction, north; the garden is nearly on a level with the pond.

The cost of irrigation.—The main items of cost are gas engine, $260; iron pipe for main, $100; the cost of the main is somewhat low, because it consists of old boiler pipe, which was secured very cheaply. The cost of the old fire hose is merely nominal, and in the experience of Mr. Hunt is an excellent substitute for iron, where no pressure is exerted. For distributing he uses hose made from 12-ounce ducking, costing 12 cents per yard; this is cut into strips, three to the yard, and sewed together and then dipped into hot coal tar; he finds it very cheap and serviceable.

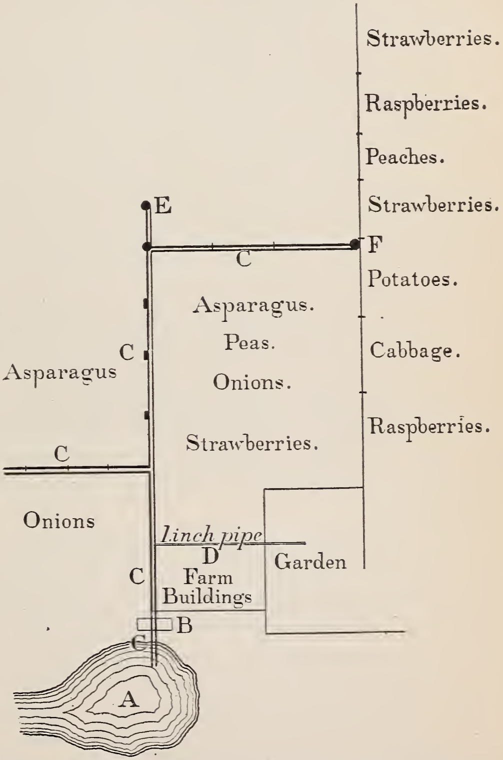

Fig. 6.—Irrigation system on the farm of T. R. Hunt, Lambertville, N. J.

The expense of running the engine ranges from 3 to 5 cents per hour, depending upon whether gasoline is purchased at retail or at wholesale, as the engine requires no attention after starting. The application of the water requires the attention of one man in order to prevent waste. It is applied entirely in rows, except upon growing plants, as cabbage and celery, when it is sprinkled.

The distribution is effected by means of a trough or gutter, the sides of which are perforated at different distances, permitting an adjustment to the width of the rows of the various crops grown. In irrigat-

ing strawberries, however, the water is simply allowed to run between the rows under the mulch. The capacity of the engine is 1,500 gallons per hour, which will irrigate thoroughly at least half an acre per day. Irrigation is never practiced until the ground becomes dry, and in the case of cultivated plants, as celery, cabbage, etc., the land is cultivated as soon after as it is dry enough, to prevent baking.

Mr. Hunt regrets now that he did not put in an engine with a capacity of 4,000 gallons an hour, a quantity that could be carried by his main, and which, at the present time, would cost but little more than the one he now has.

The advantages derived.—The first year in which the plant was in operation—1892—the irrigation of 1 acre of celery more than paid for the entire cost of the plant, and Mr. Hunt estimates that the value of the water merely for the purpose of wetting his plants, both before and at the time of setting, pays annually more than the initial cost of the plant, and though he has kept no accurate record of the profits secured from irrigation, the good results are so apparent that anyone visiting his place is deeply impressed with the value of the system. His berries, particularly, are of very fine quality; in fact, so superior that he is able to fix his own prices in his chief markets, Lambertville and Scranton.

POSSIBILITY OF PUMPING LARGE QUANTITIES OF WATER FROM WELLS FOR IRRIGATING PURPOSES.

In the two cases cited where water was pumped from wells to be used for irrigation, only a small acreage was irrigated. In order to discover if it were possible to pump large quantities of water from wells, the waterworks of Vineland, Cumberland County, N. J., were investigated.

The water for the Vineland waterworks is pumped by steam power from fourteen driven wells, 2½ inches in diameter, to a high reservoir; the distance from surface of water in the wells to the top of the tank used as a reservoir is 95 feet. The average amount of water pumped daily is 250,000 gallons. It was impossible to secure even approximate data concerning the cost of pumping this water.

The experience of the Vineland Waterworks Company proves that it is possible to pump enough water at one place, at least in southern New Jersey, to irrigate a large tract of land. Two hundred and fifty thousand gallons of water per week to an acre will irrigate most crops effectually, even during a prolonged drought. With 250,000 gallons a day from 5.5 to 6.5 acres could be irrigated without the use of large reservoirs. If large reservoirs were used, the irrigated acreage could be greatly increased.

It is not probable that such prolific wells as were found by the Vineland Waterworks Company exist in many places. But, on the other hand, not many farmers would want to irrigate more than 5 acres. It is quite probable that the most economical method of irrigation will

prove to be for several farmers to cooperate in building a central pumping station, the water to be conveyed from this station to large reservoirs on the farms of the cooperating members.

IRRIGATION EXPERIMENTS IN NEW JERSEY.

In 1895 arrangements were made that rendered it possible to secure on a farm of the New Jersey Experiment Station an abundance of water for irrigation purposes, and plans were made at once to study the question of irrigation in a broad way, both in reference to the kind and variety of crops and the methods of applying water. The cost of irrigation is not included in the study further than to record the expenses

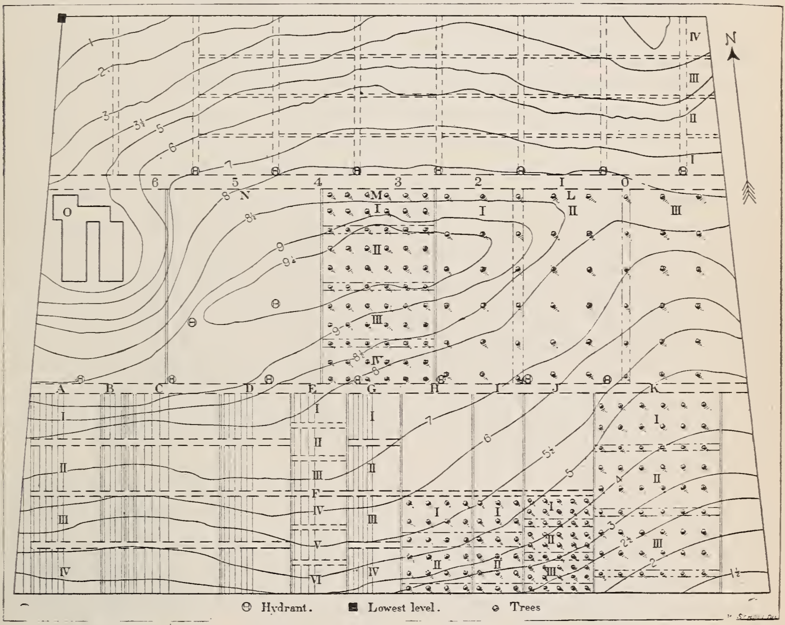

FIG. 7—Map of area devoted to irrigation experiments at the New Jersey Experiment Station.

attending the application of the water, as the conditions under which the water was obtained could not be duplicated throughout the State.

The crops that are growing now, and which are to be grown later, include a large number of vegetables, which, as a rule, require an abundance of water in order to secure earliness and high quality, and which are especially adapted to the conditions existing in the State; chief among these are asparagus, celery, cucumbers, cabbages, beets, beans, peas, peppers, potatoes, tomatoes, and turnips, including both early and late crops where the kind of vegetable permits. Among the fruits are included strawberries, blackberries, raspberries, gooseberries, currants, plums, cherries, and pears.

The methods to be investigated include both surface and subirriga-

tion. The furrow and flooding system for surface irrigation will be given careful trial, while in subirrigation both the usefulness of the various kinds of tile and the influence of depth of placing them will be studied. The plants selected include, as a rule, the standard sorts and varieties, and wherever practicable each irrigated area will include from two to four plats, each treated in a different manner, particularly in respect to manuring. The accompanying map, with description of the plant, indicates the plan and scope of the work outlined.

The experiment ground contains 7 acres, separated by lanes 9 feet wide into three divisions, the higher ground in the middle division. The contour lines show a fall of 9¼ feet from the highest to the lowest points, and that upon a large portion of the area there is a reasonable uniformity in the slope of the land, thus permitting a ready and sufficiently rapid flow of water. The water is supplied by a 3-inch main, which runs through the middle division; T's are placed every 75 feet, from which laterals, 1 inch inside diameter, are carried both north and south, ending in hydrants raised 3 feet from the ground and provided with faucets to which hose may be attached for distributing the water. The fall from the reservoir is about 9 feet, thus affording a reasonably rapid flow from the laterals, and the supply is ample for the maximum demands for irrigation purposes. The division lying on the north contains about 2 acres, and is separated into four plats, numbered in the map I, II, III, IV, which are divided again north and south into seven series of plats, indicated by the numerals 0, 1, 2, 3, 4, 5, and 6; a portion of each series, approximately one-sixth, is arranged for irrigation; the water runs north from the standpipes, and may be applied first to Plat IV, then to III, etc., or to I, II, and III, etc., as the line of experimentation may dictate.

With the exception of asparagus, the different kinds of vegetables mentioned as under experiment are grown on these plats, and various methods of surface and subirrigation used are practiced.

The area lying on the south side contains 3½ acres, and is divided into ten plats, running north and south, marked A, B, C, etc., the area of each plat being determined by the kind of crop and object of the experiment; the plats are also subdivided into belts, numbered I, II, III, etc., running east and west. With the exception of Plats B and K, one half of each plat is arranged for irrigation.

For example, Plat A contains six varieties of asparagus, represented by the lines running north and south; these varieties are duplicated on the blank space which represents the irrigated area of the plat. Plat C contains six varieties of blackberries; Plat D, six of raspberries; Plat E, four of currants; Plat F, four of gooseberries; and Plat G, six of strawberries. These plats are also subdivided into belts I, II, III, etc., for the purpose of studying methods of culture and manuring. In Plats H, containing plums, I, cherries, and J, pears, the upper portion is irrigated, and each belt of two rows of trees each in the plats is

separated from the other by a single row of trees containing different varieties of the same kind of fruit for a variety test; the purpose of this separation being to prevent cross feeding.

Plats K, in which standard pears are set, L, containing apples, and M, peaches, are situated in the middle division on the higher portion of the land, and are not duplicated for irrigation, though it may be practiced in case necessity demands. Plat N is arranged more particularly to study methods of irrigation; it contains a number of kinds and varieties of berries and vegetables in which it is planned to study the advantages and disadvantages of a number of methods of applying the water, both by surface and subirrigation methods. O shows the plant houses, where subirrigation is a feature of the work planned for the winter season.

It will be observed from this description of the plant that opportunity is afforded for a broad study of the question of irrigation as applied to the crops of the greatest importance in our State. A small part only of this plant was in operation in 1895; it was finished too late to permit of a proper study of the effect of irrigation, except in case of a few late vegetables. Irrigation began on September 17 and continued until the end of the season upon beans, peppers, eggplants, tomatoes, turnips, and celery. For eggplants and tomatoes irrigation began too late to be of service; the turnip crop was ruined by club root, thus leaving but three crops from which positive data could be secured. The complete data obtained have already been published[1] and may be summarized as follows:

[For beans, stated] in terms of good-sized pods, the average yield of the nine nonirrigated belts was 17 pounds and 1 ounce, while the yield from the irrigated belt was 45 pounds, or nearly three times as many, besides being much larger sized and of finer color and quality.

For peppers the average yield upon the eleven nonirrigated belts was 717 fruits, while the number upon the irrigated belt reached 1,277. This does not show the whole difference, for by measure an unirrigated belt gave 6½ peach basketfuls, with a total weight of 80 pounds, and the irrigated belt 11¼ baskets, weighing 147 pounds. The difference is still more than these figures show, for the irrigated ground gave much better looking peppers in plumpness and color than the nonirrigated land, with the quality far superior. The fruit from the irrigated plants would sell at the highest price, when those from nonirrigated plants might go at a low figure.

The increase of 4¾ baskets of peppers, to say nothing concerning the great superiority of the whole crop over that of the nonirrigated belts, cost for the water 24½ cents (24.46), which in round numbers is 5 cents (5.14) per basket.

The total weight of celery was 465½ pounds, 329½ pounds being produced in the irrigated and 136 pounds in the nonirrigated rows. In round numbers this is two and one-half (2.40 to be exact) times as much celery upon the irrigated as upon the nonirrigated land. However, these figures do not indicate the full difference of market value, for the irrigated celery was of good size and quality, readily salable at a fair price, while the nonirrigated rows yielded a crop that was worth less than the cost of production. After the plants were prepared for market by removing worthless outside leaves and the roots, it was shown that the loss from the irrigated

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[1] New Jersey Stas. Bul. 115.

was 28.57 per cent, while from the nonirrigated it was 40 per cent, which is a much greater loss for the smaller plants than for the larger.

The difference between the marketable products of the two rows is in round numbers three to one; but when the selling price is considered the difference is not far from eight to one in favor of irrigation.

Irrigation is undoubtedly practicable in New Jersey. It only remains to demonstrate by further study and experiment its adaptability to the varying conditions, in reference to crop and soil, the methods by which it may be most economically accomplished, and the advantages that may accrue therefrom, in order that a valuable resource of the State, namely, water supply, may be largely utilized in this direction.